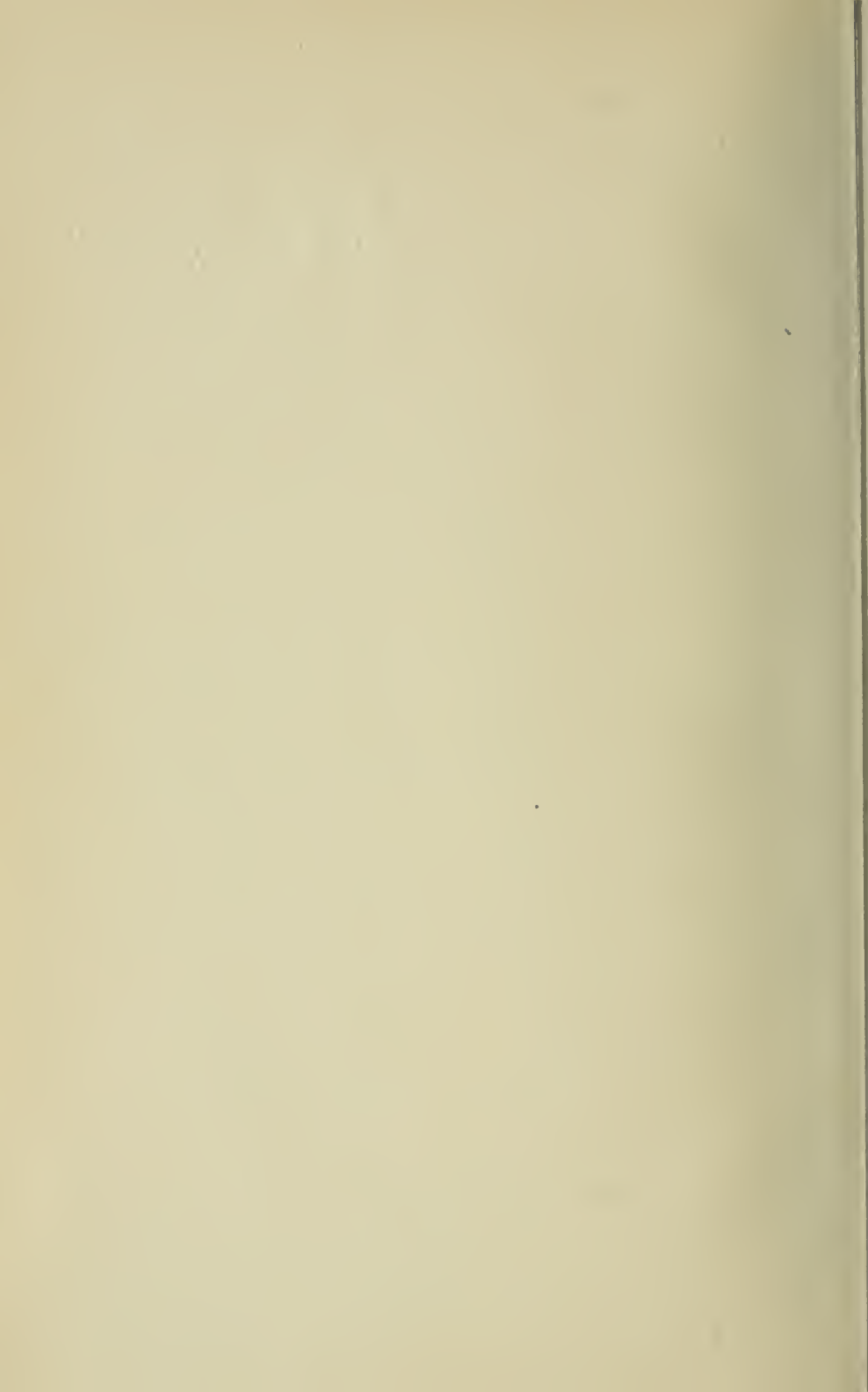






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THE JOURNAL

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FRANKLIN INSTITUTE,

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

EDITED BY

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JOURNAL OF THE FRANKLIN INSTITUTE

Vol. CLXII.—July-December, 1906.

INDEX.

Abrasive materials.....	240
Acoma: the Cliff City of New Mexico. (Carter.).....	449
Aluminum, depositing copper on.....	156
Amethysts, American.....	239
Analyses and assays free, by Government.....	370
Analytical notes—Some recently devised tests. (Leffmann).....	371
(Sadtler, S. S.).....	213
Arsenic, the recovery of.....	466
Artesian well, measuring the flow of.....	159
Balch, Edwin Swift. The survival of the shortest and easiest in language	421
Bartlett, John. On the application of Farmer's method of reduction by which the shadows are preserved and only the high-lights reduced	73
Supplementary illumination in photographic development.....	473
Baldwin, Mathias W. Presentation of portrait of.....	80
Bates, Lindon W. The terminal lake canal.....	1
BOOK NOTICES.....	476
Calcium, use of in metal refining.....	424
Carbonic acid as a cause of rust.....	157
Carter, Oscar C. S. Acoma: the Cliff City of New Mexico.....	449
Combustion, regulation of the duration of. (Eldred).....	201
Chesapeake and Delaware canal, resolution of Institute, for enlargement of. (Haupt).....	326
Chilean nitrate deposits.....	159
Chimneys. (See high chimneys)	
Civil service reform. (See Massachusetts).....	72
Claude, Georges—Low pressure: the death of matter. (Translated by Chief Eng. B. F. Isherwood, U. S. N.).....	375
Cold-worked iron, effects of strain in.....	396
Comparative strength of green Tamarack and green Norway pine....	472
Corundum, the need of.....	448
Cotton, the scouring of. (Matthews).....	25
Cryalite, importation of.....	296
Darrach, Chas, Gobrecht. The design, installation and maintenance of the modern office building.....	37, 129
Diamonds, the search for.....	212
world's famous.....	217
Easter Island, a trip to. (Frank).....	179
Earthquake records.....	335
(San Francisco), one lesson of.....	158

Effect of moisture on the strength and stiffness of wood.....	465
Eldred, Byron. Regulation of the duration of combustion.....	201
Electric fountains	344
Electricity, smelting iron ores by.....	200
Enlightened methods of treating the employed. (Porter).....	161

FRANKLIN INSTITUTE:

BALDWIN MATHIAS W. Presentation of portrait of, by Mrs. F. T. S. Sully Darley and Messrs. Burnham, Williams & Co.....	80
BROCK, ROBERT C. H. Memorial of.....	425
<i>Committee on Science and the Arts:</i>	

REPORTS:

Meeker's improvements in analytical methods and apparatus, 404; Levy's etch-powdering machine, 404; Walter & Ewing's method and apparatus for detecting electrical oscillations, 405; The "Monarch" Engine Shop.....	479
<i>Institute—Proceedings of Stated Meetings:</i>	
June 20th, 80; September 19th, 325; October 17th, 406; November 21st.....	480
Resolution urging the improvement of national waterways, particu- larly, the Chesapeake and Delaware Canal.....	326
<i>Sections—Proceedings of Stated Meetings.....</i>	478
<i>Schools:</i>	
Schools of Drawing, Machine Design and Naval architecture.....	76
Farmer's method of reduction in photography. (Bartlett).....	73
Ferrocyanide titration.....	396
Fluorescence and phosphorescence. (Nichols).....	219
Fluorspar, production of, in 1905.....	239
the uses of.....	336
Frank, Victor Strauss. A trip to Easter Island.....	179
Ganz, Albert F. The physical meaning of power factor, and the signifi- cance of a power factor less than unity without phase difference..	429
Gem mine, the greatest in the world.....	240
Hammer's historic collection of incandescent electric lamps. (Report on).....	329
Hart, Jas. H. Application of mechanical refrigeration to ice cream manufacture	397
Haupt, Lewis M., Relations of the Government to our waterways.....	320
Heating value of coal and crude oil.....	157
Henry, Alfred J. Weather forecasting from synoptic charts.....	297
High chimneys, danger of, in earthquake countries.....	370
Ice cream manufacture, application of mechanical refrigeration to. (Hart.)	397
Incandescent gas mantles, behavior of.....	159
lamps, Hammer's historic collection of. Report on.....	327
International Association for Testing Materials.....	396
Injector, high-pressure, steam tests of. (Kneass).....	279
Iron ores, smelting by electricity.....	200

Isherwood, B. F. (See Claude.)	
Job, Robert. Testing and inspection of railroad supplies.....	31
Kinetic energy of gases, development of the theory for.(Westman)...	317, 383
Kneass, Strickland L. High-pressure steam tests of an injector.....	279
Lapidary work: A growing industry in the United States.....	296
Lead peroxide manufacture.....	428
Leakage, direct, of steam through slide valves. (Stanford.).....	467
Leffmann, Henry. Notes on some recently devised tests.....	371
Legislative Engineering. (Trautwine.).....	407
Locomotive, the most powerful.....	128
Low pressures: the death of matter. (Claude-Isherwood).....	375
Mann, Arthur S. Superheated steam in the power station.....	291
Manufacture of lead peroxide.....	428
Maple product, a note on the examination of. The lead value. (Sy)....	71
Massachusetts Civil Service Reform Bureau.....	72
Matthews, J. Merritt. The scouring of cotton.....	25
Mercury arc, the: its properties and technical applications. (Weintraub)..	241
Metallurgy, recent progress in. (Outerbridge).....	345
Metallies	471
Mica, the production of in 1905.....	419
Moisture, effect of on the strength and stiffness of wood.....	465
Nichols, Edward L. Fluorescence and Phosphorescence.....	219
Nitrate deposits, Chilean.....	159
Obituary Notice. Robert C. H. Brock.....	425
Office buildings, modern, the design, installation and maintenance of. (Darrach)	37, 129
Open-hearth bath, premelting addition to.....	369
Outerbridge, A. E. Recent progress in metallurgy.....	345
Panama interoceanic canal. (See Bates)	
Paper-making machine, the largest.....	158
Perrine, Frederick A. C. The value and design of water-power plants as influenced by load factor.....	269
Petroleum of North America, &c. (Richardson.).....	57, 81
Phosphorescence. (See Nichols.).....	219
Porter, H. F. J. The democrazation of industry; or enlightened meth- ods of treating the employed.....	161
Power factor, the physical meaning of, etc. (Ganz.).....	429
Practical hints to quarrymen.....	420
Precious stones, production of, in 1905.....	239
Premelting addition to the open-hearth bath.....	369
Production of mica in 1905.....	419
Quarrymen, practical hints to.....	420
Railroad supplies, testing and inspection of. (Job).....	31
Reclamation service, annual report of.....	75

Recovery of Arsenic.....	466
Richardson, Clifford. The petroleums of North America: a comparison of those of the older and newer fields.....	57, 81
Rust, carbonic acid as a cause of.....	157
Sadtler, Samuel S. Analytical notes.....	213
Salton Sink, the.....	23
Scandinavian water power.....	316
Scouring of cotton. (Matthews.).....	25
Smelting zinc ore in the blast furnace.....	428
Soda spring, a remarkable.....	24
Soft graphite made electrically.....	448
Stanford, J. V. Direct leakage of steam through slide valves.....	467
Steel, vanadium.....	218
Subway, proposed for Pittsburgh.....	374
Superheated steam in the power station. (Mann).....	291
Supplementary illumination in photographic development. (Bartlett.).....	473
Survival of the shortest and easiest in language. (Balch.).....	421
Sy, Albert P. A note on the examination of maple product. The load value	71
Tamarack and green Norway pine, comparative strength of.....	472
Technical notes.....	218
Terminal lake canal at Panama. (Bates.).....	1
The need of Corundum.....	448
Tin in Southern Nigeria.....	278
Topaz. (See tourmaline.)	
Tourmaline and topaz, in Southern California.....	212
Trautwine, J. C., Jr. Legislative engineering.....	407
Transformers and transformer iron, standard test for.....	316
Turbine engine, variable speed	428
Turquoise, California, in favor.....	200
Use of calcium in metal refining.....	424
Vanadium steel.....	218
Variable speed turbine engine.....	428
Water-power plants, the value and design of, as influenced by load factor. (Perrine)	269
Scandinavian	316
Weather forecasting from synoptic charts. (Henry.).....	297
Weintraub, E. The mercury arc: its properties and technical applications	241
Westman, Gustaf M. Development of the theory for the kinetic energy of gases	317, 353
Zinc industry in Utah.....	395
ore, smelting in the blast furnace.....	428

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THE FRANKLIN INSTITUTE.

(Stated Meeting, held Wednesday, September 20th, 1905.)

The Terminal Lake Canal.

BY LINDON W. BATES.

Much prominence has been given to the Minority Report of five members dissenting from the sea-level proposition in favor of an eighty-five-foot canal. It has not been so generally noted that the Terminal Lake Canal, with a summit level of sixty feet, was supported by a vote of nine to four in the Board of Consulting Engineers as the best lock type for the Panama Canal. The main features of this canal, which are very simple, may be shortly described.

On the Atlantic the canal cut begins near the head of Limon Bay. A low dam at Gatun, or preferably at Mindi, impounds Lake Chagres at a level of about thirty feet, entered by the first lock. This lake submerges the terminal swamps adjoining the canal and gives free open sailing as far as the second dam and lock, which makes the summit level lake at an elevation of sixty feet. At Gamboa, where the Chagres meets the canal, a

sluice dam guards the canal from floods. The regulated flow of the river enters the canal and is divided, part going to the Atlantic and part of the Pacific. This is the system accepted likewise for the Board's Sea-level plan. At Pedro Miguel the third lock marking the Pacific end of the summit level lowers the vessel into Terminal Lake Panama at twenty-six feet level. The fourth lock in the Acon-Sosa saddle lowers the ship into the Pacific.

This sixty-foot-level canal warrants attention, not alone from its endorsement by the nine eminent engineers whose votes were cast for it as the best lock canal, but because of its conformity to three principles which amount to engineering axioms, each of which the higher lock canal of the Minority violates.

The first of these relates to dimensions—with the growth of ship sizes, the maximum usable dimensions of locks should be 1000' by 100' by 40', and there should be room at lock sites for even greater dimensions. The canon of lock dimensions is violated by the minority in that their locks as planned are of but 900 by 90 feet usable dimensions. The locks designed and adopted for the latest of Europe's national undertakings of this nature,—the Grand Coupure of Antwerp,—will take a vessel 984 feet long. The lock dimensions voted in the Board of Consulting Engineers by 11 to 2 before the division as to type took place, were 1000' by 100' of usable length. The length of 900 feet is too meagre a limitation to put on the size of vessels passing through the canal.

Still more significant is the inability to lengthen these locks to the full 1000 feet and have these vital structures founded in solid strata. The Gatun Hill is too low and too narrow for longer locks to be founded in rock. Their sides would project from forty to sixty feet above the rock line and would have to be built up to, with massive concrete structures. The whole flight instead of being securely buried in the rock, would be perched on the hill like three great boxes propped by concrete buttresses.

The sixty-foot canal obeys the canon of lock dimensions and lock foundation. The lock at Mindi, that at Gatun (or Bohio), the third at Pedro Miguel and the fourth at the Ancon-Sosa saddle are all of full 1000 feet length and founded in solid strata.

A second axiom is:—the hazards of over-running lock gates should eliminate from consideration the arrangement of locks in flight, one above the other. The experience of the Manchester Canal gives some idea of how fatal a defect is this scheme of locks in flight. No less than three times has a vessel crashed through its locks—with relatively small damage because the difference in levels was but eight to nine feet. The Minority violates the canon against lock flights in their three at Gatun and their two at Sosa. By the law of averages it is certain that at some time sooner or later a signal will be mistaken, an engineer pull the wrong lever, or the steering gear break at a critical time and an accident happen to a lock gate. Should this occur at an upper gate where the vessel starts to go down the ladder of three locks, the result would be inevitable and appalling. The enormous momentum of a great ship, with the mass of 40,000 tons of steel and cargo, could, though going at greatly reduced speed, crush the massive gates like matchwood, as the French liner went through the North River pier not long ago. The current would sweep the vessel over the lower gates and a released lake eighty-five feet high would pour out through the lock opening, wiping out like an avalanche everything below and making a loss to the canal itself irreparable for years.

The sixty-foot lock canal has no locks in flight, all are separated. An accident would loose at most thirty feet of water, and this would go into a broad lake below to be discharged with a minimum of damage through a large number of safety sluices. Further, with locks far apart, there can be put a middle gate in the lock for use with all except the comparatively rare, very great ships. With this, two closed gates could always intervene between the upper and lower levels and these would be 300 to 400 feet apart.

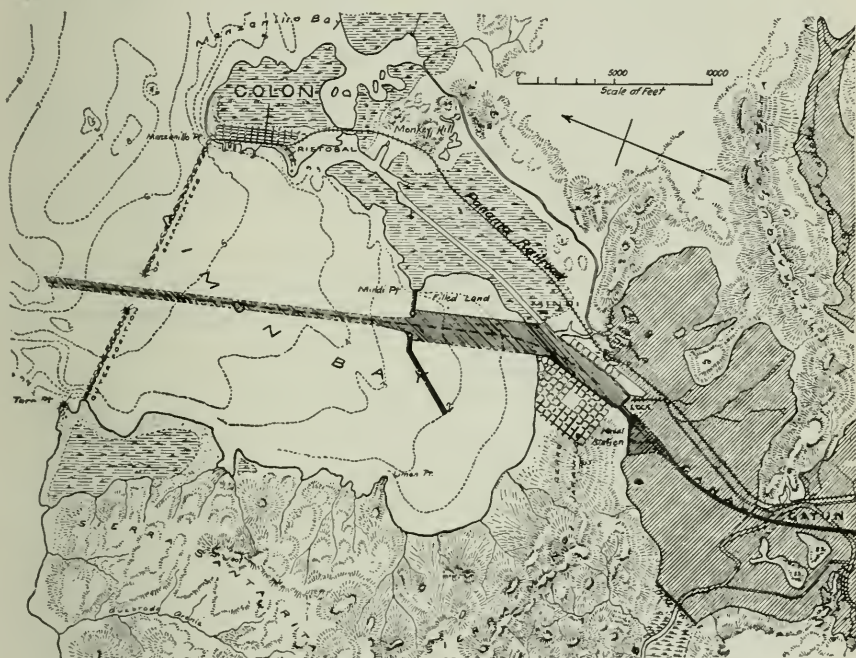
Finally there is the canon of the head of water to be allowed on impounding structures. Theoretically a dam can be built as high as one pleases if percolation is blanketed by a long enough backing to it. As a matter of actual practice there is a more or less well defined limit beyond which a conservative engineer does not go. On the alluvial foundations of the Isthmus no dam should be made with a greater head than forty feet to keep within the most assured limits of engineering security.



The Terminal Lake Canal, summit level 60 feet. Three navigable lakes, no dam with a head over 30 feet net head, locks widely separated, never in flight. Chagres regulation by empty basin system and Assuan type dams.

The minority's eighty-five-foot lake violates this by imposing a full eighty-five-foot head.

The sixty-foot plan keeps within the bounds of conservatism by making no head over thirty-six feet. The main dam has sixty feet of water in Lake Gatun-Bohio above and thirty feet in Lake Chagres below. The head producing percolation which is the difference in levels, is thus but thirty feet, which is absolutely safe and unquestionable.



Balboa Harbor: Proposed Terminal City of Balboa, having an inner Fresh Water Harbor on Lake Chagres and an Outer Salt Harbor at the head of Limon Bay. The new sanitary city built on hill on American Territory, Colon on its marsh being abandoned.

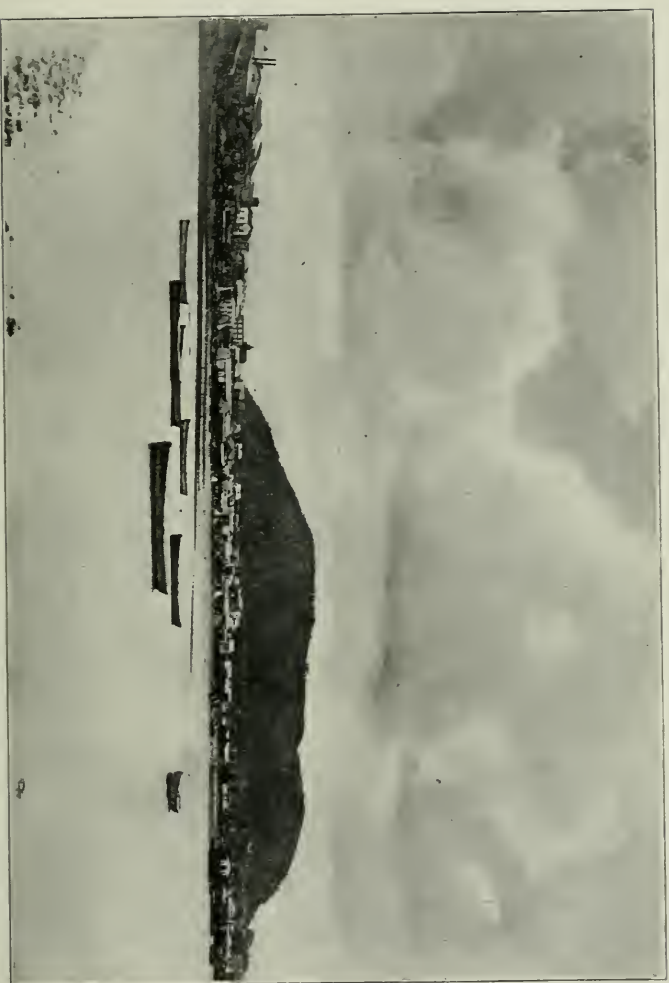
So significant are these deficiencies and inferiorities of the Minority's plans; its limitation of vessel size; its imposition of a monstrous and experimental dam; and its perilous arrangement of locks in flight, that the writer considers it rightfully eliminated as against the sixty-foot lock plan.

The superiority of the latter is in fundamentals and is inherent in the sixty-foot canal, either as originally proposed by the writer, or as modified by the Board in their final proposal.

As given forth by the Board, two sites are selected which were offered as second choice instead of first when the writer's Terminal Lake Canal was laid before them. Bohio is taken by the Majority as their site for a summit level dam and Gatun for the lower level, while the original plan preferred Gatun as the summit level site, because seventy-five per cent. more water flows past it, giving a greater lockage capacity, and Mindi as the lower dam site because it gives three more miles of lake navigation and submerges three more miles of swamps. One further item defines the latest official plan. The Majority propose at Gamboa one high dam impounding a permanent lake. The original plan was for a Gamboa dam of similar nature, but of less height, and a duplicate at Alhajuela, thus averaging the control over two low dams rather than concentrating it on one high dam. But these are obviously matters of detail only.

Having weighed the sixty-foot plan against the Minority's Gatun Dam Lock flight scheme, the final comparison is with the Sea-level.

Before, however, making the comparison, the writer desires to complete the description of the sixty-foot canal by including his unadopted provisions for terminal harbors. In none of the Board reports are full plans made for the future canal ports. Only at the Atlantic terminus were any proposals relative to them advanced. These consisted in five miles of breakwater at depths and on foundations undetermined, whose cost must vastly exceed the large estimate, and designed to make a port at swamp-founded Colon. There was submitted in the writer's project an inner harbor making a protected anchorage at the head of Limon Bay. It was proposed to abandon Colon with its miserable wooden shanties built on stilts over Manzanillo Marsh on Panama territory, and to establish a new city on American territory near the Mindi canal entrance. Here, where the first lock enters Lake Chagres can be built a sanitary terminal on a rocky hill. In front will be the salt harbor in the head of the bay. Behind it a clean fresh water lake submerging all the festering swamps under thirty feet of clear water. The inner fresh water harbor would be free from tide and current and would be sheltered from all storms and waves. Under the hill on the lake can be established a



The Panama Bay front : It is proposed to reclaim the tidal flats with Culebra spoil, much of which would otherwise be wasted at sea. The hill is Ancón, behind which, on Lake Panama, could be made, an impregnable naval station.

naval station which could not be reached by hostile cannon. This is the port of Balboa, which is proposed for the Atlantic terminus.

For Panama, breakwaters were designed, whose arms were to enclose the whole harbor and La Boca and to terminate at the rocky harbor islands. These breakwaters would encircle and create the safest, largest and best harbor of the South Pacific, with scarcely more cost than would be required to get rid of the material by wasting it at sea. Within them the whole of the Culebra can be placed out of reach of erosive currents and can serve the splendid future of Panama. Here is the best and closest site upon which to deposit Culebra spoil rather than waste it at sea or spread it over the swamps at a heavy toll of life. And by this a new and greater Panama is created with an inner fresh harbor on Lake Panama matched by an outer harbor protected by the breakwaters, a combination unequalled in the water reaches of the globe.

As these inner fresh harbors and all the advantages they give cannot be available to a Sea-level canal, which is all salt water, they furnish one most vital point of preference over it. The Board did not include any harbor arrangements save the long Colon breakwater on the plea of cost. They state,—

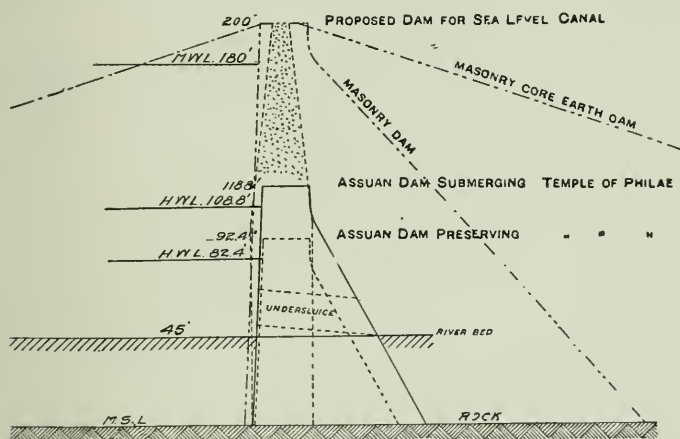
“Much more *elaborate harbor constructions* and the more costly character of *their appurtenant works* chiefly account for the excess of the estimated cost of Mr. Bates’s project over that of the sixty-foot summit level lock plan of the Board.”

Since, however the proposer figured on contract prices rather than government execution prices, costs may not be so high as the Board estimates.

In the comparison of this lock and lake canal with the Sea-level, its far better terminal facilities of the sixty-foot canal are one point of superiority. Beyond this, however, every canal plan must be judged by the way it measures up against the elemental standards of security, cost and time of execution, convenience to navigation. It must stand or fall by the adequacy with which it meets these demands.

The first measuring rod for any canal is fundamentally the one of safety. The Sea-level scheme when it was presented to the Board included a three and a-half mile tunnel along whose

walls of volcanic conglomerate the eroding Chagres discharge was to tear, a disposition of the greatest danger. The revised Sea-level plan has not this objection. The adoption of the writer's Chagres flood solution has obviated this peril. The incorporation of a Gamboa sluice dam from which the regulated discharge, being divided, passes into the canal prism and thence goes to either ocean, has taken away the menace of the Chagres torrents for all normal conditions. But for a deviation from the normal, the Sea-level is still an unsafe canal and in an earthquake-visited tropic land this factor dare not be discounted. There is no guarantee against a repetition of the



Sea Level Dam vs Assuan Type : The Sea-level dam is much higher and sustains a permanent lake. The Bates dam impounds no water, save in time of great floods.

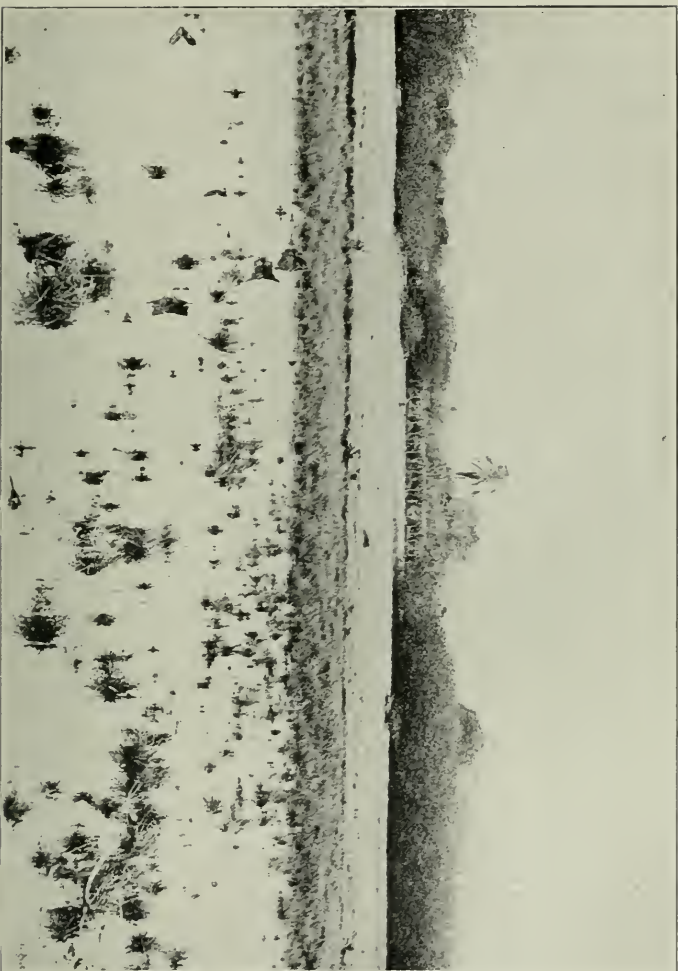
series of shocks which opened a gap across the main street of Colon and destroyed the Cathedral tower at Panama. The great permanent lake above Gamboa, on the latest Sea-level plan and the three others at Cano, Giganté and Gigantito, in the light of such possibilities, are three perpetual dangers.

Each dam holds back a deep lake at an elevation of from 55 to 170 feet above the canal. A breach in any of these three through an earthquake or subsidence, or fissure, or any of the other causes which make dams fail, would let loose a wave from 55 to 170 feet high to sweep destruction down the canal. As against this element of danger the sixty-foot canal as planned with the empty basin system has no high dams or high heads of

water like those four of the Sea-level. At Gamboa and Cano and at Alhajuela the sixty-foot canal has low dams, and instead of a permanent lake, the valley behind them is normally empty and no water is impounded save at floods. Only when an exceptionally heavy torrent comes are the sluices partly closed and water impounded, and this only for a maximum duration of fifty-six hours. The rest of the time the river flows quietly through the sluices. Five times in thirty years alone would it have been necessary to impound water behind the writer's proposed dams, for there were only five floods which could not have been allowed to pass the sluices. An earthquake, to have injured seriously the canal protected by these sluice dams with normally empty valleys behind, would have had to destroy the dam during one of the fifteen days in thirty years when there was water behind it. Any time during the remaining twenty-nine years, three hundred and fifty days, these dams could be shaken without finding any volume of water there to release. Three large deep lakes imminent and vulnerable every day in the year in the Sea-level plan as against three basins with water in them only five times in thirty years, is the measure of comparative safety afforded by the two canals in this respect.

A second point which should be considered in the two channels is, which will be the best from the navigator's standpoint? Very many railway engineers have been asked their opinion as to the canal, but very few of the principal navigators who will be called upon to take their ships through. But it is surely important for a waterway, which is built for the highest service to commerce, to know what sort of a canal a commander, anxious to score well with Lloyds and the ship owners, would prefer. First of all, he would want a straight entrance, clear of reefs and well protected. He would want a mooring place and a wharf space where he could have plenty of room. The harbor and the harbor entrances would be his first thought.

As to the canal proper, his demand again would be, plenty of room for steerage purposes, that there need be no danger of sheering against the sides or colliding with passing ships and plenty of water under his keel. Measure with such a standard as this and the superiority of the sixty-foot lock-and-lake canal,



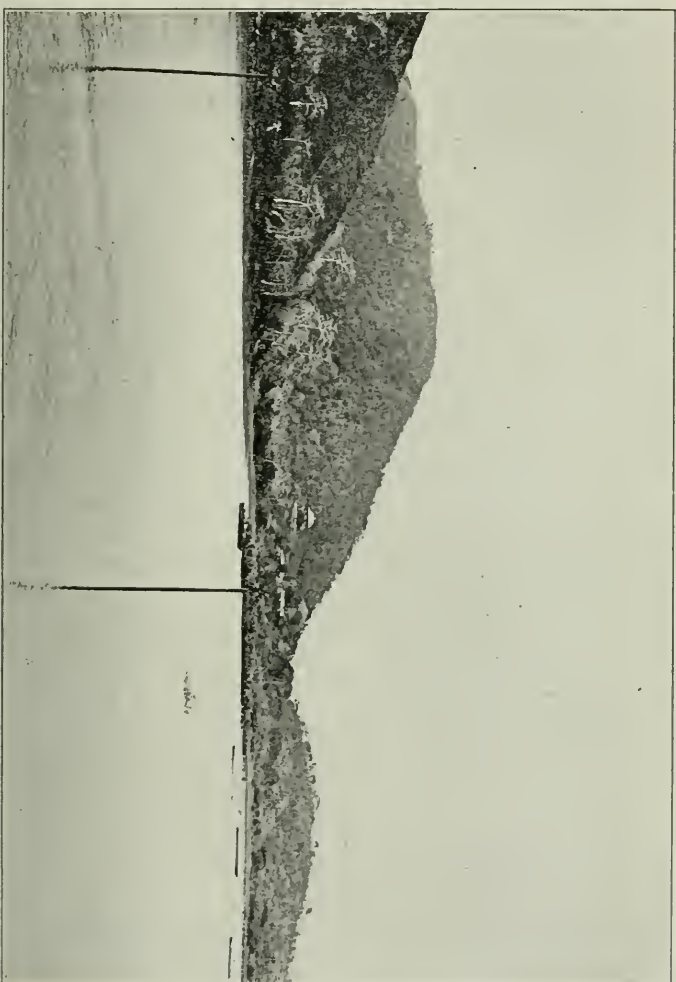
Terminal Swamp : These will be submerged under twenty-five feet of water, giving open sailing and making great sanitary improvement.

with the terminal harbors as elaborated, is not hard to demonstrate.

The Sea-level plan offers him, at Colon, a salt water bay whose approach is immediately to windward of Colon Reefs. At Panama it furnishes him nothing beyond the tide harried roadstead with an entrance directly across the San José Reefs. The harbors and harbor entrances of the writer's lake canal would be the best in the world, in the combination of a commodious outer harbor and inner water basin, free from tides, where the fresh water will kill barnacles and the ship worm, is ideal. The entrance contours are well beyond the reefs on each side and lead straight to the canal entrance without a curve.

On entering the canal proper, the navigator would, in the sea-level, start on his forty-six-mile passage through a constricted rock-flanked cut with the certitude that he would have to lay up for repairs if his vessel struck its walls. He must, all along the route, tie up in the pockets cut alongside the channel, and wait while other vessels passed him. He must move at very reduced speed in rounding all curves and so lose steerage way for two-thirds of the line. He must endure all the torment of the poison-laden swamps flanking him. At Culebra he would be deep down in an artificial gorge with the imminent clay-conglomerate towering above him on either side. Here and there he would have to squeeze by a dredge, clearing away the sediment brought down by the rain-swollen streams. The prospect to the navigator of insuring safe passage in a Sea-level canal at Panama would not be the most alluring.

The alternative which the sixty-foot canal holds out to him is open lake navigation for twenty-six and a-half miles, in which he could move at twice the speed which he could be allowed in a constricted channel. Other vessels could be seen for miles ahead, be allowed for and readily passed. There would be no sheering against banks, since ample steering room would be given. He would have no dredges to dodge, for all slit would be deposited where the streams enter the lakes, miles away from the canal, or be localized in special slit traps. For only nine miles through the Culebra would a channel exist such as the sea-level proposes for its entire length. But here the banks on either side would be much lower and so less dangerous as to



The Ancon-Sosa Saddle: The Pacific Lock is located here. It will lift a vessel about twenty-seven feet into Lake Panama.

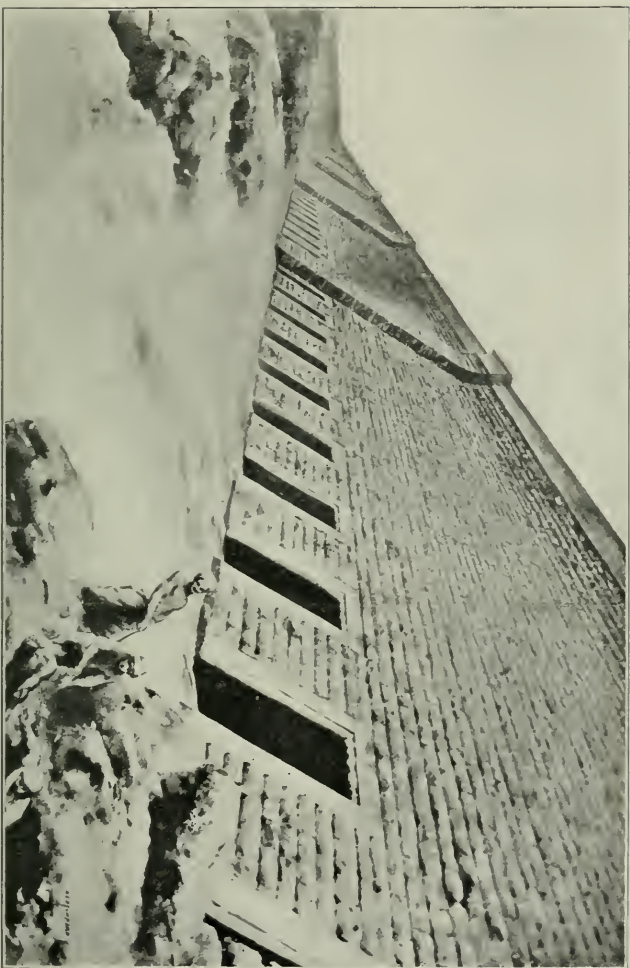
land-slides. Because of the doubly greater speed, which a large ship could be allowed in a lake, its time of transit, counting in the lock passage, would be reduced by three hours. The ability to pass other ships, when the traffic of the future has become great, would be of incalculable benefit.

It has been testified that a certain Sea-level plan has less curvature than a lake canal. But such a statement as this is most misleading. When a vessel changes her course in a lake waterway the pilot does not reduce speed; in a Sea-level canal he must slow down. Applying this principle, it is the simple truth that a lake canal has but a third to a quarter of the curvature *affecting navigation* that the Sea-level scheme has.

Another standard for comparison is the time for construction. All other things being equal, a canal which can be traversed in eight or nine hours and can be available in eight years is better than one which demands three hours longer for a large vessel and which will not be ready for sixteen years.

Just when can a Sea-level canal be completed? Ten years is the latest figures of the ex-Chief Engineer for a canal forty feet deep. The Commission of 1901, making a careful estimate, gave twenty years as the minimum, and they were calculating upon only a thirty-five foot channel. Nine months ago the official figure for a thirty-five foot channel was given as sixteen years. The Commission now estimates eighteen years. Who, then, is to judge when doctors so disagree? Allowing themselves grace in the Majority's official figure, a forty-foot Sea-level channel across the Isthmus is to be, they claim, available in, at most, thirteen years. But it is only a much qualified estimate, based upon no guarantee whatever.

The truth of the whole matter is that no one knows at all, or can possibly know, when such a canal will be finished. If one goes over the list of the world's canals, having excavations of mixed materials and takes their rates of excavation, the result is surely a warning for the sanguine advocates of the Sea-level. The Chicago Drainage Canal was dug in one-mile sections by private contract, getting intimate personal supervision of the most interested kind and employing the most modern machinery. It was excavated at the rate of five and a-half million yards per annum. At this output a Panama Sea-level canal would require forty-seven years for its completion. Yet this.



The Aswan Dam : A masonry dam of exactly this height and nature is proposed at Alhajuela and Gamboa to control the Chagres.

Chicago canal was dug in the temperate zone under none of the tropical conditions that will prevail at Panama. It had competent white labor. The Chairman of the Commission testified that Isthmian labor averaged one-quarter northern efficiency. The downpours, the lack of adequate labor, the rapidity of rot and rust, the illness and deaths, these may set the time for completion anywhere between fifteen and fifty years.

With the sixty-foot lock-and-lake canal, on the contrary, the time is not subject to the uncertainties involved in this huge mass of excavation. To make three low earth dams of standard type across the river valleys is easy and straightforward and an actual work of but few months. By making them, twenty-six and a-half miles of the canal's total land length of forty miles is turned into lake, needing incidentally but a small amount of soft dredging. An ocean steamer could then steam up to either end of the Culebra cut. The much smaller volume taken from the Culebra would be attacked by dredges or Lobnitz machines from either end, with water transportation for the spoil and by land plant with rail transportation as well. With such a program as this a minimum time may be realized and the canal can be contracted for under bond in at most eight years.

There is finally the extremely important question of cost. Assuredly no one wishes an inferior canal, be it cheap or dear. But dearthness is in itself an element of inferiority, if the same or a better waterway can be had for less money. The fact that money is not the first and most important element is far from being a reason why it should be disregarded utterly. It is an axiom of political as well as business economy that the sacrifice entailed should not exceed the good gained. The good to be secured by an Isthmian canal may be measured fairly and accurately by the use which will be made of it. The Commission of 1907 made a minute investigation of the commerce that would reasonably be expected to use the canal if constructed. They figured that, so regarded, the Panama justified as a national investment about the sum of \$145,000,000 for its construction. Considering it as capitalized at this amount, and allowing ten years for its construction, the canal would thus just about repay interest and cost and yield enough for maintenance.

On the basis of these figures, Congress rejected the Nica-

SCALE

Lincoln H. Bates
2/15/03



СЕРТИФИКАТ 1900
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rauguan proposition and invested \$50,000,000 to secure title to Panama. Now the Sea-level proposition is brought forward, proposing a construction cost of at least \$247,000,000. Sanitation and Zone Government, which were not included, bring the figure up to \$263,000,000. This is to be paid out with no return for thirteen years and probably with some fifty years of deficits in income to follow that. The whole balance and equilibrium of the first conservative proposal is destroyed. It is not even claimed to be worth while as an investment. In bright generalities our astonished Congress is called upon to vote \$128,000,000 more than was ever bargained for and to undertake a Sea-level canal with DeLesseps' technical and financial failure staring them in the face, and with each of its different advocates making conflicting estimates of time and cost.

Consider the figure set by the Board of Consulting Engineers, \$247,021,200. The price of this revised Sea-level scheme is scaled to the lowest possible, leaving out items of great import in order to bring the figures down. The Panama Port Works, heretofore rated at \$10,000,000, were omitted. Sanitation and Zone Government were omitted, though they are certainly indispensable and every previous plan included them as a matter of course. These features of sanitation and zone government must cost at least \$16,000,000 more in thirteen years construction time. Add these items and the proper total becomes at least \$273,021,200 on the Board's own unit prices. Is there any guarantee that this sum will not be exceeded? None whatever. The figure itself is simply an approximation. Detailed designs for engineers estimates under the new tropic conditions are not forthcoming. There is no assurance that the cost will not be more than \$300,000,000, with a century's deficit in the canal's operation.

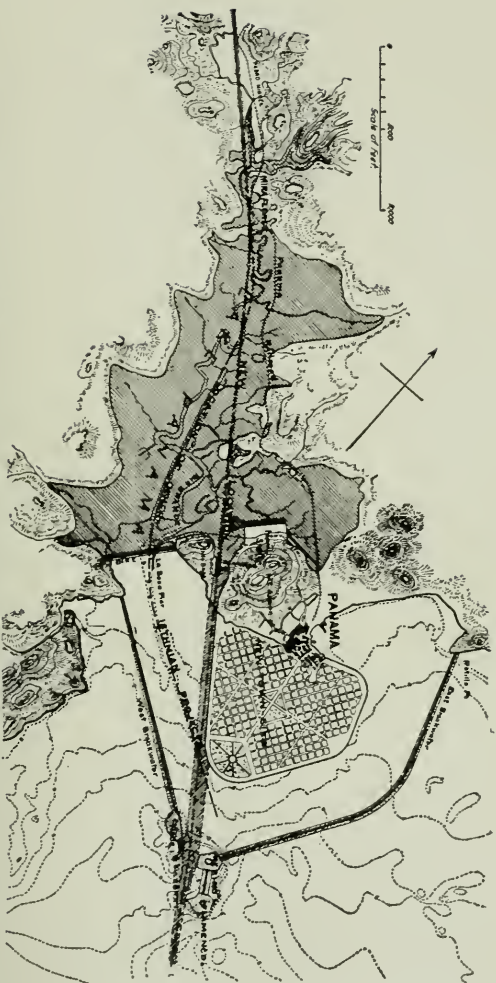
With the sixty-foot canal the same elements that make time calculable make cost calculable also. The impounding structures, which mainly constitute it can be closely figured. The excavation of which the Sea-level chiefly consists cannot. In French times the unit cost per yard in the Culebra Cut varied from fifty-two cents to \$6.80. In the small digging which we have had, it has varied from 50 cents to \$1.54. Weather conditions, the amount of pumping, the difficulties attendant upon a huge force of crude labor, all are elements of hazard, far

greater in the Sea-level than in any other type of canal. The maximum price figured by the majority was \$176,000,000 as an engineer's estimate and \$146,666,667 as a contracting estimate for their sixty-foot canal as planned, and they were committed to the Sea-level, a rival type. With the single modification (decreasing excavation) of adopting the Mindi site, there can be fully constructed the sixty-foot canal at \$3,125,000 a mile, or a total of \$124,000,000 construction cost, making with sanitation and zone government \$135,000,000. The essence of the situation is that most of the Sea-level work is digging and this has a large element of uncertainty. Most of the lake-canal work is low structures of masonry, which has a very small element of uncertainty.

But assume that the Sea-level would cost \$263,000,000, which is the Board's figure, plus the very moderate figure of \$16,000,000 for sanitation and zone government. Take simply the difference that exists on the face of the estimates, \$128,000,000, and consider whether the American people want to spend that amount extra to get a canal thirteen years hence which it takes a great ship three hours longer and much more hazard to pass through.

Congress passes periodically a River and Harbor Bill to improve our American ports. If this extra \$128,000,000, which the Sea-level advocates assure us we can easily afford, were put into port works, what could be accomplished within our borders? The entrance channels to New York harbor, affecting every ship captain and owner doing business there, could be dredged out and established to forty feet, \$10,000,000; the Cape Cod Canal could be cut \$10,000,000; Portland, Oregon, could be made safely available to the largest vessels afloat, \$6,000,000; Charleston Bar could be better jettied and so permanently removed, \$7,000,000; the Mississippi Levees and port protections re-inforced, \$11,000,000; San Diego Harbor dredged and made available to the largest vessels, \$6,000,000; Chicago Harbor protected from northers by stone breakwater, \$7,000,000; the Sacramento leveed and dredged, \$5,000,000; Galveston Causeway to the mainland constructed, \$1,000,000; and still there is \$65,000,000 left for public buildings and improvements. This is what the spending of \$128,000,000 in terms of things.

What is the gain of the Sea-level? In only one feature has



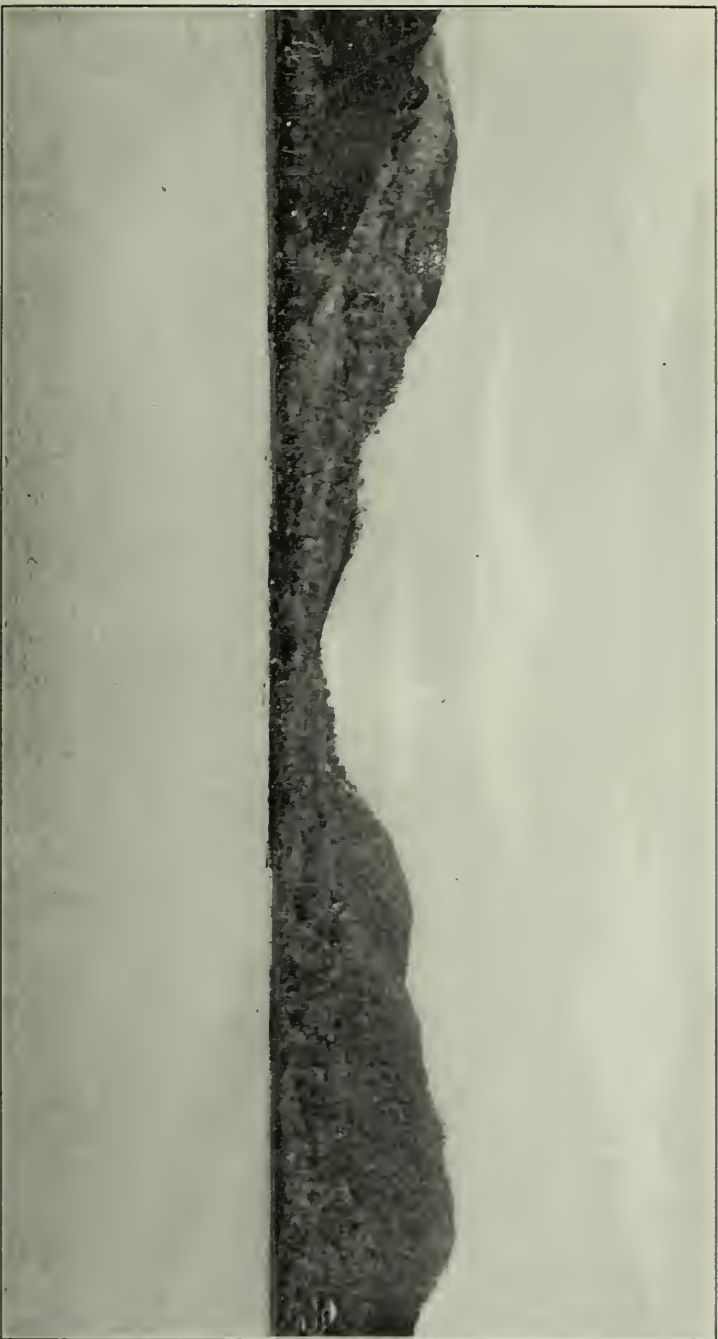
Greater Panama: The breakwaters and new town-site reclaimed from Culebra rock are shown and Lake Panama made by two short embankments and entered by the Ancon Sosa Lock.

it any claim to a superiority; the apparent advantage one lock over four. But their cost is made insignificant by the cost of the Sea-level excavation. The expense of maintaining them will be passed by that of keeping silts out of the one-lock canal. Any risk of passing them is more than offset by the risk of navigating a winding constructed canal. The time lost is more than decompensated by the lakes and made three hours shorter for large vessels. Is it worth while to exchange this illusory advantage of one lock over four, for the real advantages that accompany the features of the Lake Canal?

This question is not simply one of academic interest to be looked at from afar off as though it concerned a canal on Mars. One of the canal plans must be adopted, the others rejected. One canal must bear for all the future the commerce of the world, while the other plans are relegated to the dusty tomes of engineering history. The plan which is to pass from lines upon paper to the mighty waterway that cleaves two hemispheres cannot be determined by a sentiment or an illusion. The facts and all the facts must be weighed, considered and then definitely and finally acted upon. The conclusion which is indelibly engraven on the very nature of the facts is that the advantage of a Sea-level's one lock over a sixty-foot canal's four is too dearly purchased, at the cost of peril in each passage through its constricted, rock-flanked cuts; of the slower transit in its lakeless channel; of an extra expenditure of at least \$128,000,000; of the retardation of completion by at least seven years.

There is a final matter which does not perhaps fall within the province of engineers called upon to face only mathematical possibility of harnessing the Chagres and piercing the Culebra, but which certainly does fall to the consciences of the nation commanding the work.

Under the project which the writer has advocated one year of work and every swamp near the canal line will be drowned beneath twenty-five feet of clean water. The number of laborers that would be used in a Sea-level would be reduced by one-half and the work would be largely done by water-borne machines. The stygonia larvæ could not live under such a depth of water, and if they could oil spread over an open and accessible sheet of water would kill them, where it could not be applied to the myr-



Canal Entrance : Between Ancon and Sosa Hills is the Pacific entrance. Both of these hills can be fortified.

iad isolated unreachable jungle pools. Terminal cities started *de novo* and begun rightly would supersede the old, around impregnated with filth germs from the garbage of half a century. New terminal cities on high ground, the fever swamps submerged, the use of floating dredges reducing the army of laborers—this is the supreme sanitary policy.

In that first Congress of 1879, where the foremost figure in the engineering world had swung his whole weight to the Sea-level waterway, one man rose up with his fatefully true prophesy against the great Frenchman's visionary ideal. This was Godin de Lepinay, the first man to propose terminal swamp-submerging lakes for the Panama Canal.

"All my conscience is intensely enlisted. I am the only French engineer a member of this Congress who has executed work in that country there. If I have not known how to make my advice triumph, I cannot let it be believed that I abandoned it, all unknown though I am. I shall have gone out of this assembly, as others have done, that I may not leave my name subscribed to a measure disastrous.

"Finally, and this is the greatest with me—me who has executed works in that tropical America; reducing these unsanitary works to their minimum, spares the life of more than 50,000 men, uselessly sacrificed for the execution of a sea-level project. To not charge my conscience with these unnecessary deaths and the loss of a considerable capital, I abstain, or I vote, No."

How true was his forecast the world knows too well.

A new generation of engineers now rallies to the old dream of De Lesseps,—forgetful of his silent buried cities. He, too, had great hospitals and disinfectants and new-built dwellings and a host of doctors. But could any sprinkling of chloride around camps, any screening of wires on windows, any water works or commissaries, any surface disinfection or spreading of cil remove the death that lurks in the steaming miles of jungle swamp that compass then round about?

For the greater part of its length, a canal dug at sea level must be cut down to its depth of forty feet below mean tide,

through the Isthmian morasses. To permanently drain these swamps is impossible. To fill them would be a labor of immortal gods, not of men. When the pioneers of the Panama Railroad undertook to drive one single line of railroad through to the foot-hills, it took them years and an appalling loss of life. What would be the price of life to fill them all, or to fill even a half mile strip along the canal? An army of doctors and "weeding engineers," with all the resources of modern science, could not kill the stygomia larvæ in the myriad isolated festering pools, and just so long as these swamps are allowed to breed death just so long will the Isthmus be the white man's grave. What must result when excavation begins in earnest and ground is newly broken all across the Isthmus, is not hidden. It can be read on the tombstones of Monkey Hill; in the tragedy of Matachin, "slain Chinese village;" in the cluster of drooping crosses behind Ancon, in the bitter legend of a lost man, warden of each rail of the Panama Railroad. Just as surely as the rising of the sun, a decision for a Sea-level canal dooms to death an army.

THE SALTON SINK.

A map representing parts of California and Mexico has recently been published by the United States Geological Survey which is of unusual interest at this time. The area covered is widely known as the Salton Sink, a great depression in the Colorado Desert which has been much discussed lately, owing to the threatened formation of a large inland sea where there is now a thriving community.

About 8000 people have settled in that part of the basin known as the Imperial Valley, and are raising excellent crops of barley and alfalfa. Stock farms are numerous and experiments in raising the date palm are in progress. The freight shipments from Imperial, a town only four years old, rival those of Los Angeles in value, and are said to exceed those of any other town in Southern California.

The existence of this peaceful community is, however, seriously endangered by Colorado River, which, strangely enough, is also the source of all its prosperity, as it is this stream which furnishes water for the irrigation system. The absence of any controlling work at the head of the main canal has resulted in diverting the river from its old channel and permitting the entire flood flow to enter the irrigating system. This is causing great damage to the ditches and crops, and is forming a large lake, which now

covers about 250 square miles, at the lowest part of the Sink. The Southern Pacific Railroad has been obliged to rebuild many miles of tracks.

The map of this region, which is called the Salton Sink Special, shows on a scale of about eight miles to an inch, all the principal towns, roads, canals, and drainage lines. Contour lines also indicate what the future sea may cover at different altitudes. The usual price of five cents a copy will be charged for this map, which was made by Mr. W. Carvel Hall, under the direction of Mr. R. B. Marshall.

A REMARKABLE SODA SPRING.

BY J. A. EDDY.

Undoubtedly one of the most remarkable springs in the world has recently been discovered in New Mexico. It is literally a spring saturated with sodium sulphate. Distilled water weighs 8.33 lbs. to the gallon. The water of this spring weighs 10.66 lbs. per gallon; and evaporation yields 3.13 lbs., of dry solid matter, of which 83 per cent. is sulphate of soda, crystallizing out chemically pure.

The sulphate of soda crystal contains 87 per cent. water. At 110 degrees F. it melts in its own water of crystallization; and the temperature of the spring being slightly in excess of 110 degrees F., the saturated liquid upon flowing and cooling immediately forms a crystalline mass like ice.

The natural inquiry arises as to the deposit or accumulation of ages from this spring; for, unless it discharged into a stream of fresh water, the deposit would be vast in extent. No more fitting location could be imagined, for it is in the lowest portion of the vast sink or basin, scores of miles in extent.

The deposit therefore has formed a vast bed, miles in extent, of solid sodium salts, through which this spring, by reason of its heat, maintains its channel and continues to augment the deposit. Inasmuch as the soda crystal efflorescences, or gives up its water by evaporation, the elements serve to smooth and level the surface; so that the lake, though dry, is white as snow and bears some resemblance to a Northern lake in the embrace of winter.

It would seem impossible for either animal or vegetable life to exist in this hot brine, or in the dry soda of the lake surface; and yet the brine is inhabited by a minute shrimp-like organism, and a species of plant is often found thriving in the pure white sodium sulphate.—*Eng. and Min. Journal.*

Section of Physics and Chemistry.

(Stated Meeting, held Thursday, May 3d, 1906.)

The Scouring of Cotton.

BY J. MERRITT MATTHEWS, PH. D.

Professor of Chemistry, Philadelphia Textile School, and Lecturer on the Chemistry of Textiles and Pottery, Franklin Institute.

1. *Introductory.*—Before cotton can be properly dyed or bleached, it is necessary that the waxy matters surrounding the fibres should be removed. As these are water-repellent, it is very difficult to impregnate the cotton fibre with solutions if such impurities are present. This may be rendered easily apparent by placing raw cotton in water, even at a boiling temperature, and noticing how long a time is required for the fibres to become wet through.

Unless it is to be dyed or bleached in the loose state, cotton in this form, is seldom scoured out, as the amount of foreign matter on the fibre is nowhere comparable to that on wool, and it in no way interferes with the carding or spinning. In fact, the waxy matters on the cotton fibre are of great assistance in the proper carding and spinning of the material, as it gives a coherence to the fibres which would otherwise be lacking. Cotton that has been scoured and bleached in the loose state is very difficult to properly spin, and oil must be added to the stock in the same manner as with wool.

2. *Nature of Impurities in Cotton.*—The cotton fibre, though usually considered as consisting of practically pure cellulose, contains about five per cent. of foreign matter other than the true fibre. The majority of this consists of a thin layer of vegetable wax and pectin, which forms a coating over the surface of the entire fibre. This wax, as already noted, gives the raw cotton fibre its water-proof or water-repellent character, and is also very serviceable in giving the fibre a certain degree of plasticity during the spinning operations. Underneath the layer of wax

is a very thin cuticular tissue, which also covers the fibre proper. This, no doubt, consists of an alteration product of cellulose, produced through the action of the air, and merely acts as a limiting surface to the matrix of cellulose beneath. In the inner portion of the fibre, forming the wall of the central canal, there is also a very thin integumental tissue, or skin, which is, perhaps, of somewhat the same character as the outer skin. Within the canal itself there is also always more or less dried-up protoplasmic matter, consisting of nitrogenous substances and resinous matters derived from the dried-up sap, which during the life of the fibre circulated through this canal. There is also a small amount of oily matters present in the fibre, derived, no doubt, from the oil of the cotton seed, and contaminating the fibre as a result of the process of ginning. Finally, the cotton fibre contains a minute quantity of coloring-matter, doubtless of a catechin-tannin variety. In some varieties of cotton, as in the Egyptian and Nankin, this coloring-matter may become quite pronounced, and give to the fibre a distinct yellowish-brown color.

It is customary to consider the impurities of the cotton fibre under two general headings: (*a*) *cotton wax*, and (*b*) *pectin bodies*; the latter consisting of the albuminous or nitrogenous substances already spoken of.

Dr. Schunck has made a careful investigation of the impurities existing in the cotton fibre, and the following summary of his results may be given: Besides the hygroscopic moisture, crude cotton appears to contain about five per cent. of non-cellulosic matters, which may be classified as follows:

(*a*) *Cotton-wax*, bearing a strong resemblance to carnaüba wax; it is insoluble in water, but soluble in alcohol and also in ether.

(*b*) *A fatty acid* which has a melting point of 55.5° C., and appears to be either margaric acid or a mixture of palmitic and stearic acids.

(*c*) *Two brown coloring-matters* of a nitrogenous character; one is easily soluble in alcohol, and the other but sparingly so.

(*d*) *Pectic acid*; a light yellow amorphous substance, similar in character to gelatine or a gum. It is soluble in water, and is acid in reaction. It exceeds all the other constituents in amount.

(c) *Albuminous matter* of a nondescript character.

3. *Theory of Cotton Scouring.*—The process of cotton scouring is most generally spoken of as "boiling out." The state in which cotton is usually operated on is either yarn or cloth; loose cotton is only scoured when it is desired to have it bleached in this form, more especially for the preparation of absorbent cotton or for use in cotton bats. Cotton yarn and cloth, however, must always be thoroughly scoured previous to bleaching, and also frequently before dyeing or mordanting; although in the latter case, the object of the scouring is only to cause the cotton to wet-out readily and absorb the solutions with which it is treated; consequently the scouring in this case is by no means as thorough as when it is desired to subsequently bleach the cotton, when all the impurities must be completely removed.

There are two general processes by which cotton may be scoured; the one is by the use of alkalies, such as soda ash, caustic soda, or lime, whereby the waxy matters on the fibre are removed in the form of an emulsion, and the pectin and other matters are decomposed by the alkali into soluble substances; the other method is by the use of certain oils, such as Turkey-red oils, sulphated cotton-seed oil, etc., whereby the waxy matters are dissolved-off and very rapidly removed from the fibre; although the other impurities are but slightly affected. The former method removes or decomposes all of the impurities, whereas the latter only removes the wax and makes the cotton absorbent towards water, so that it may be readily dyed. In some cases of bleaching, both methods are combined, and as we shall afterwards see, both possess certain special advantages of their own.

The treatment of cotton in scouring or boiling-out, will depend on the purpose for which the cotton is intended. If the scouring is merely for the purpose of wetting-out the fibre so that it may be more readily dyed, then the scouring is only a partial one, chiefly with the object of removing the waxy matters. If, however, the scouring is for the purpose of completely cleansing the fibre of all impurities in order that the cotton may be well bleached, then the boiling-out is a very thorough one. We will discriminate between these two methods by calling them "wetting-out" and "boiling-out."

To obtain the best results, cotton yarn or cloth should always be wet-out thoroughly before being dyed or mordanted, as if this is not done, there is danger of having spots or uneven streaks through the goods, by reason of insufficient penetration of the dye liquor. In the case of some dyes where the color goes on very slowly and evenly, and where the material may be boiled a long time in the bath before the dyeing is finished, this previous wetting-out may not be absolutely necessary, as the boiling water itself brings this about. This is usually true of the general class of substantive cotton dyes, though in this case a small amount of alkali or oil may be added to the dyebath itself, and in this manner the wetting-out is greatly facilitated. In case of dyes which go on the fibre quickly, or which dye at temperatures below the boil, it is almost an absolute necessity to have the cotton first wet-out before placing it in the dyebath. The same is also true in the case of mordanting, especially so, as cotton does not possess any great degree of attraction for the majority of mordanting salts, and unless well wet-out the fibre will only be poorly mordanted. In the case of mordanting with tannin, where a boiling bath is used (as is sometimes the practice), the previous wetting-out operation may be dispensed with, and the cotton wet-out in the mordant bath itself; the same is also true when the cotton is steeped in the tannin bath over night; but where the tannin bath is used at a lower temperature than the boil (as is most frequently the case), the cotton should always be first wet-out, otherwise when the material is dyed, small white specks will show up, caused by lack of penetration of the mordant.

For the proper bleaching of cotton goods it is absolutely essential that all of the foreign matters present in the fibre be removed, in order that the cellulose be pure and that a good clean white be obtained. This is true both where the cotton is bleached for the purpose of being left in the form of white goods, and also where it is to be subsequently dyed with such coloring-matters as alizarin for Turkey-red, and for the general purposes of printing. In the two latter cases the bleaching must be especially thorough in order to obtain the best results in dyeing and printing. These processes are more especially used on cloth; for yarn the bleaching does not have to be so thorough. As the boiling-out of the cotton is so intimately

connected with the actual process of bleaching itself, and as the one process really forms a continuation of the other, the two must be considered together under the one subject of bleaching.

Cotton which is intended to be dyed cold should be very thoroughly scoured, otherwise the dyeing will be imperfect. Also yarns made from Makko, or Egyptian, cotton require a more thorough treatment than usual, as they contain more fatty and waxy matters than ordinary yarn. In the scouring of very fine yarns the material should be enclosed in sacks in order to prevent it from becoming felted.

4. *Scouring Cotton with Alkalies.*—The usual method of wetting-out cotton with alkalies is to boil it for an hour or two in a weak solution of soda ash. After this process it is washed in clean water, and is then ready for dyeing. A weak bath of caustic soda may also be employed for this purpose, but this is not used as much as the former. Caustic soda is more difficult to remove afterwards from the fibre, and so causes loss of time in unnecessary washing, whereas liquors of soda ash are very readily washed out of cotton, and even in many cases, the washing may be entirely dispensed with, when the dye-bath to be used is alkaline in character. It requires at least an hour's boiling in the bath of soda ash before the cotton will be completely wet-out, although the operation should not be limited to any fixed time but should be continued until it is seen that the material is thoroughly impregnated with liquid; in the case of yarns, the inside of the hanks should be opened out and examined for any dry spots. Tightly twisted yarns will naturally require longer to wet-out than single and loosely twisted yarns. Sometimes yarns are spun with the addition of oil to the stock, in which case it is advisable to add a small amount of soap to the scouring bath.

Müller has studied the effect of different alkaline agents in the wetting-out of cotton for dyeing, and the summary of his results are as follows: Using a pure, well-made soap wets-out cotton better than a sulpho-ricinoleate, olive oil soap giving the best results and palm oil and olein soap a slightly inferior result. In using a hard water it is necessary to add some soda ash in order to obtain good results.

5. *Scouring of Cotton with Oils.*—It has been found that certain oils possess the property of readily dissolving waxy mat-

ters present in the cotton fibre, so they may be used for the purpose of wetting-out cotton for dyeing. The oils referred to fall under the general class known as sulphated or soluble oils, of which Turkey-red oil is the principal representative. Turkey-red oil is so called because it is largely used in the mordanting of cotton for the subsequent dyeing with alizarin for the production of a bright red. True Turkey-red oil consists of sulphated castor oil, produced by the action of concentrated sulphuric acid on castor oil. The resulting product is an oily looking substance which is soluble in water. Other vegetable oils may be used for the same purpose, and sulphated cotton seed oil is largely used, as it is considerably cheaper. A number of proprietary preparations of these oils are on the market, among which may be named Fankhausine, Solvine, etc. Some of them also contain small amounts of mineral oil, and some contain alkali, soap, tallow, etc., for the purpose of softening the cotton. They are known under the general name of "cotton softeners." Scouring with oil leaves the cotton in whiter and softer condition, the time required for wetting-out is much lessened and the scouring can be done at a much lower temperature. The amount of oil to be added to the bath need not be more than one to two per cent. on the weight of the cotton, and in many cases it may be added directly to the dye-bath, and the cotton be wet-out before the coloring-matter is added. In almost any case, it will hardly be necessary to wash the cotton off after scouring, as the small amount of oil which would be carried over into the bath would have no effect on the dyestuff. In the case of basic dyes, however, the oil cannot be added directly to the dye-bath, as an insoluble compound with the coloring-matter will be formed. When mordanting with tannin, also the scouring must take place in a separate bath.

Turkey-red oil causes a considerable bleaching of cotton when used for boiling-out; in fact, Hartel claims that a pure white can be obtained in the following manner: The cotton is impregnated with a solution of Turkey-red oil of about ten per cent. strength, wrung out and dried. The material is then boiled for six hours under pressure with about two per cent. of caustic soda, rinsed, slightly scoured, rinsed again, soaped slightly, rinsed and finally dried.

Mechanical and Engineering Section.

Testing and Inspection of Railroad Supplies.*

BY ROBERT JOB.

Chemist of the Philadelphia & Reading Railway Company.

In the time at our disposal to-night it will be impossible to give more than a very brief outline of some of the more important testing regularly carried on by the Philadelphia & Reading Railway.

The main object of the Test Department is to determine the kind and quality of material most efficient and economical for any given purpose, and then by means of routine tests to hold shipments fully up to the desired standard. The plan usually followed is to get together all the information obtainable regarding the particular article to be investigated, decide through study of service tests just what properties are essential to the greatest efficiency, and then work out specifications which will enable the manufacturer to understand thoroughly just what kind of material is desired and what tests must be met to insure acceptance of shipments.

These proposed specifications are referred by the Purchasing Agent to the manufacturers for their criticism, the replies are sent to the Chemist, and a final draft is then prepared with any changes necessary, submitted again if needful to the manufacturers and finally to the First Vice-President for approval.

Orders are then placed in accordance with the new standard, and on receipt of each shipment a sample is selected at random and forwarded for test. If the sample is not in accordance with the specifications the shipment is rejected, and the freight is paid by the shipper. In this manner inferior material is weeded out from the good, and discarded.

*Read by title.

Iron in one form or another is, of course, an important item of railroad supplies. Bar iron, and the better grades for bolts and for staybolts come under this head, and also rivets, steam pipes, boiler flues, chain, iron castings, wheels, etc.

The quality is determined in part with the so-called "test machine," by which the tenacity and ductility of the metal are measured;—the cold bending test develops any cold-shortness, if present, and the hot bend any red-shortness or failure to bend when red-hot. If too much sulphur is present the iron will crack on bending hot, while excess of phosphorus will cause cold-shortness. More than a trace of copper will prevent proper welding,—and too little working in the rolls, or finishing at too high a temperature will result in brittleness, and be indicated by the bright granular condition of the fractured surfaces, instead of the long, ropy, fibrous appearance indicative of toughness and strength.

The pig-iron used for making cylinders and other castings must be low in phosphorus or the metal will be weak and brittle,—not too high in manganese and sulphur or it cannot be machined,—and close-grained and compact to insure strength and impermeability. Analyses are made of samples from each carload of pig-iron to hold it to the proper quality, and the foundry practice has been carefully studied, and treatment is applied to render the iron tough, strong and ductile.

Tests of cast-iron wheels for freight cars are made at the place of manufacture and involve measurements and weight and general inspection, and a "drop test" made by allowing a weight of 140 lbs. to fall upon the wheel from a height of twelve feet a specified number of times, depending upon the weight and size of the wheel,—twelve blows for the usual 33" wheel.

Materials of steel are of great importance, since they include such products as boiler steel, axles, rails, splice plates, springs, piston rods, crank pins, castings, general forgings, building material, etc. In fact, the very stability of the structures, the engines, and equipment depends in large degree upon the quality of the steel and iron. In the case of boiler steel, a test piece is taken from every sheet and given a tensile test to ensure the desired strength and ductility, freedom from flaws, etc.; a bending test is made after quenching, to avoid possibility of brittle-

ness, and also chemical analysis to determine and bar out more than a certain proportion of phosphorus and sulphur.

Steel rails, splice plates, axles, piston rods, crank pins, and springs, are inspected at the manufacturing plant. Each spring is pressed down solid in a testing machine, and must also have a certain height under a given load, be of correct design, etc. Also an analysis is made of one spring of every 200 to determine whether the steel may be depended upon to give good service.

Axles in addition to the usual surface inspection and measurement are subjected to a drop test to ensure freedom from brittleness, and they are also held to a definite composition to enable them to support the loads and give reliable service. Rails likewise have composition specified to secure proper hardness and toughness, and a drop test is made upon a rail-butt from each heat from the top of an ingot, allowing a 2000 lb. weight fall a distance of twenty feet striking the rail midway between two supports four feet apart. If the steel is brittle and unsafe for use, owing to defective manufacture, pipes, flaws, etc., this 40,000 foot-pound blow speedily renders the fact evident and breaks the rail, sometimes into splinters. In some cases, especially when steel has given poor service, it is necessary to make a microscopic investigation of the structure of the metal to find out the exact conditions of heat-treatment received in course of manufacture, for as is well known, good steel can be completely ruined by incorrect heat-treatment. If the steel was overheated or burned, and thus was rendered brittle and untrustworthy, the fact is clearly shown by the microscopic structure.

Passing now from iron and steel, we may mention protective coatings for metal or wood. Paints to-day are used in enormous quantity, and it is of great importance to obtain the utmost durability not merely in order to afford the necessary protection and appearance, but also to reduce labor costs and to avoid the need of frequent shopping of equipment and consequent withdrawal from urgent service. The paints are separated into their constituents and the purity or efficiency of each is determined. The linseed oil must not be of poor quality or adulterated with fish oil, mineral oil, corn oil, etc.; turpentine must be really turpentine and not benzine; and japan must be up to the specified strength and quality.

"Hot boxes" are generally due to difficulty with oil, wool-waste, or bearings, and each of these materials are held to a definite standard. A week often passes without a single hot-box upon any of the passenger equipment of the Reading.

Wool-waste for freight service must contain at least sixty-five per cent. of pure wool and be of fair length of thread, or the waste after short service would lose its elasticity and fail to remain in contact with the journal, thus cutting off the feeding of the oil to the axle.

The oil must have correct flashing and burning points, be of proper viscosity and have enough fat oil to make the mixture adhere to the steel. Signal oil must be of standard composition and quality so that the wick in the lamp will hold the flame in a gale of wind; headlight oil must not explode even when hot and jolted.

Also each kind of machinery must be lubricated with oil adapted to its weight and speed,—or loss of power, heating, or rapid wear will result, with heavy bills for maintenance or repairs.

Air-brake hose must stand a pressure of 400 lbs. per square inch, and the rubber must be tested to prove whether or not it is so adulterated with shoddy, mineral matter, paraffine, tar, etc., that its life will be gone and it will be useless within a few months. The battery materials to operate the electric track signals with which our tracks are protected must be found so free from impurities that the service rendered will be absolutely reliable.

Portland cement is very largely used in construction work, and gives excellent results when the quality is good. It may, however, be unsound and cause the work gradually to disintegrate, or it may be shipped out by the manufacturer while it is too fresh,—not properly aerated,—and if used then the concrete would not prove lasting but would crack and weaken; in these cases careful tests indicate the quality, and they often keep from service material which would have caused failure and perhaps accident.

The water supplies, both for steam and for drinking purposes, also require careful attention. The former must be of a character that will not corrode the boiler, nor on the other hand fill it with scale and necessitate frequent cleaning of the flues,

and waste of fuel, since scale one-eighth inch thick means a loss of fuel of twenty-two per cent. ; also, the character of the water must be so regulated when necessary by treatment, that foaming and liability of explosion will not be possible.

Every water supply upon the Reading is tested from time to time ; bad waters have been abandoned, and other supplies substituted, or, if nothing better is available, treatment is applied to neutralize the injurious results which otherwise would follow.

Every water used as a drinking supply in stations or upon cars has also been carefully analyzed to be certain that it is as free as possible from contamination.

Whenever desirable, bacteriological examinations are made to determine whether a water supply in some locality may have become contaminated and caused typhoid fever or other disease which developed.

Tin plate and roofing tin sometimes have so thin a coating of tin or composition that rusting begins after exposure of a day or two upon a roof, and we have actually received shipments in which the thickness of the tin coating averaged less than $3/100,000$ of an inch. Such material of course has little practical value other than that of the steel sheets of which it is composed, and the latter could be secured at far less cost than probably would be charged for the so-called "tin plate."

Insulated signal wire is tested to determine whether the copper is pure, and the rubber and other insulation of standard quality.

Soap must be free from excess of alkali, salt, and other impurities, and must not be adulterated with clay or other "fillers," and must not contain more than a definite proportion of water.

Enough instances have now been cited to convey some idea of the great variety of tests and inspections regularly made by the Test Department. In addition to such routine work, investigations are made upon materials which may have given unsatisfactory service, or which apparently have not been exactly adapted to the conditions under which they were used, in order to determine just why the failure occurred, or the service was defective, and the data thus obtained often results in revision of specifications with consequent improvement.

Investigations are also made to devise new methods for use

or renewal of waste materials or to develop new processes, large savings having been effected through such work.

The preservation of wood is a subject of the greatest importance to every railroad, and a very careful investigation has been made of all processes used and results obtained both in this country and abroad; also tree-planting upon the land at our disposal has been looked into thoroughly and estimates obtained as to the cost and ultimate return from such investment under our conditions of place and climate.

From the foregoing brief account of work of the Test Department, the fact will, I think, be evident that a persistent and earnest effort is being made to secure the grades of material best adapted to the various purposes, and such effort naturally results in relatively great durability of material, and thus in great ultimate economy combined with a high degree of safety and of efficiency in the service.

READING, PA., Feb. 16, 1906.

(Stated Meeting, held Thursday, April 5th, 1906.)

The Design, Installation and Maintenance of the Modern Office Building.

BY CHAS. GOBRECHT DARRACH, C.E., ETC.

As experience in any art is of prime importance, to one who has to speak about that art, and as the speaker's experience in designing the mechanical equipment of office buildings has been a long one, he ventures to think, that a paper, based largely upon it, will be of more service to the Institute than one, however carefully prepared, but based upon information acquired in a less exacting school.

He says this because he wishes to apologize, once and for all, for the personal note, which appears in this discussion, and which he fully realizes to be, if undesirable, yet of unavoidable frequency.

He trusts that a free discussion will not only mark his errors, but also elucidate more fully those important subjects which he attempts to bring to your notice.

The modern office building is a national triumph, and in our own city one of the first office buildings was erected—the Bulitt Building, opened for use about 1887. I think the Empire Building, in New York, was the precursor, but neither of these buildings were fireproof.

Community of interests, required the study of the needs of the various tenants and of the ways and means to serve them, both individually and collectively, not only with all modern comforts, but also with all the varied apparatus of the most advanced science, at such a cost of service, that the old system of segregation of offices would be abandoned.

The office building became a city. The tenant, with the advantage of absolute privacy, possessed the means of perfect communication with the outside world, and could be reached

in person or by voice, by telegraph or by letter, as readily if desired as could the greatest magnate of the land.

It was not long before these advantages were appreciated, and individual offices in separated buildings, became not only suburban, but as it were isolated in some vast prairie.

It is my purpose this evening to give a brief review of the design, construction and of the mechanical installations required to meet the necessities of these internal business centers, vieing in population and importance with many of the larger cities of a quarter of a century ago.

The development of science was the precursor of the office building, and I think you will agree with me, that except in magnitude, in some minor improvements in apparatus, and the addition of a few luxuries, the designers and engineers of twenty years ago solved the problem.

DESIGN AND CONSTRUCTION.

DESIGN.

Looking backward to the Drexel Building, in Philadelphia, designed in 1886-7, the following cardinal points were considered and fulfilled to the then state of the art :

1st. That the building should be fireproof.

2nd. That the means of ingress and egress should be so arranged, that no matter where located, the various offices should have equal advantage.

3rd. That the building should be so designed that the greatest proportion of rentable floor-space could be utilized and that, that space could, without structural change, be subdivided into a minimum sized office, lighted by one window, and at the same time be provided with all the conveniences of the larger subdivisions.

There are but few of the best modern office buildings which fulfil these conditions, and the only additional advantage which the tenant appreciates is, that he has, in his office, a hot water tap and a cold drinking water faucet.

To enumerate the conveniences, in addition to those heretofore mentioned, there were provided :

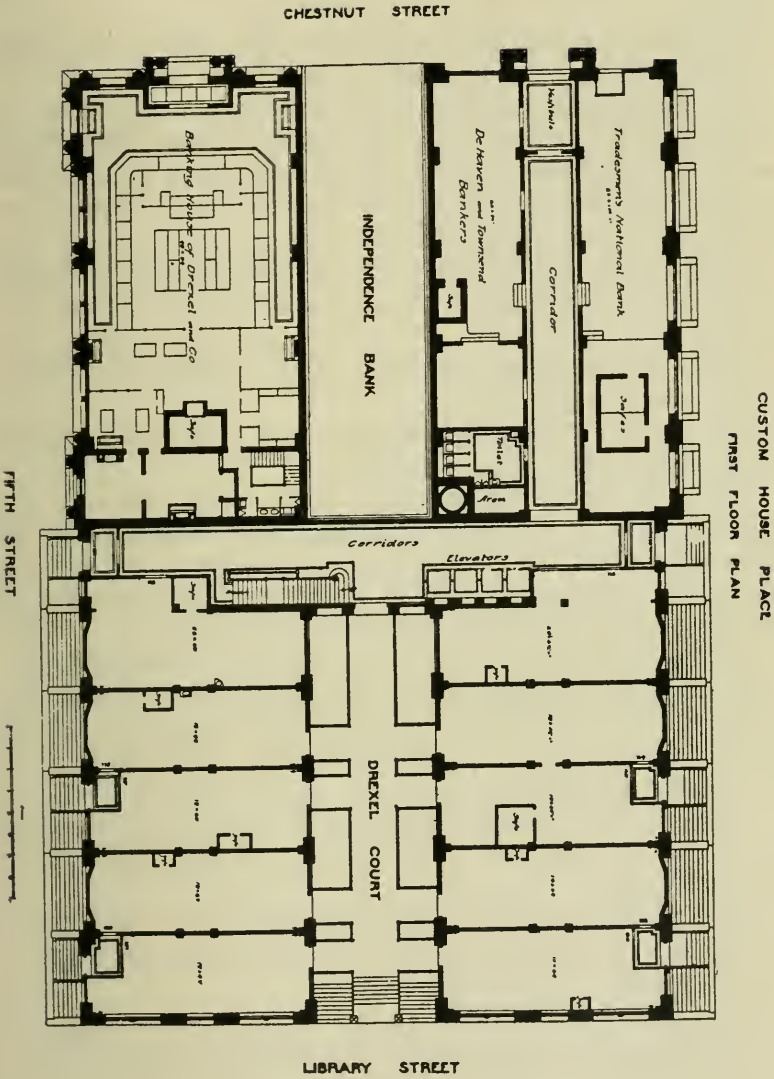


Illustration Special Floor. (1887.)

High-speed elevators, with safety devices.

Steam heat, radiator under each window and under individual control.

Filtered water-supply and basin for each office, with supply reservoirs in the attic, supplied from pumps.

Fire protection, including water at high-pressure in supply mains, with nozzles and hose on each floor, the system being served automatically from the tanks in the attic as well as by fire pumps in basement and supplemented with chemical fire-extinguishers and water buckets.

Toilet rooms on each floor, with all conveniences, including hot and cold water, as well as housemaid closets and sinks with hot and cold water.

Direct-current electric lighting, with combination fixtures for illuminating gas.

Telephone and telegraph conduits and distribution to each office, and letter drops at each floor.

An office for the Superintendent and Chief Engineer, not only adjacent to and in direct communication with the boiler and engine room, but also convenient of access to the tenants. The Chief Engineer's office, in addition to the conveniences furnished to the other offices, contained the electrical distribution switchboard with meters and apparatus indicating the work done in the boiler and engine-rooms; it also had individual telephones, speaking tubes and bells connected with the office of the owner's representative, as well as with the more or less remote employees.

Adjacent to the Engineer's office, the Matron (controlling the female help and who could confer with lady tenants) was located.

The Boiler and Engine Rooms, and coal storage, of ample dimensions, with good light, excellent ventilation and low temperature, occupy the entire basement,

At this point I should like to lay particular stress upon the necessity, and the humanity, of this arrangement.

Of necessity, the working parts must, if efficiency is to be expected, be in view and subject to easy inspection and repair.

Apparatus crowded together cannot but escape the attention of the Chief Engineer and Superintendent, who has the burden and responsibility of the entire management, including not only

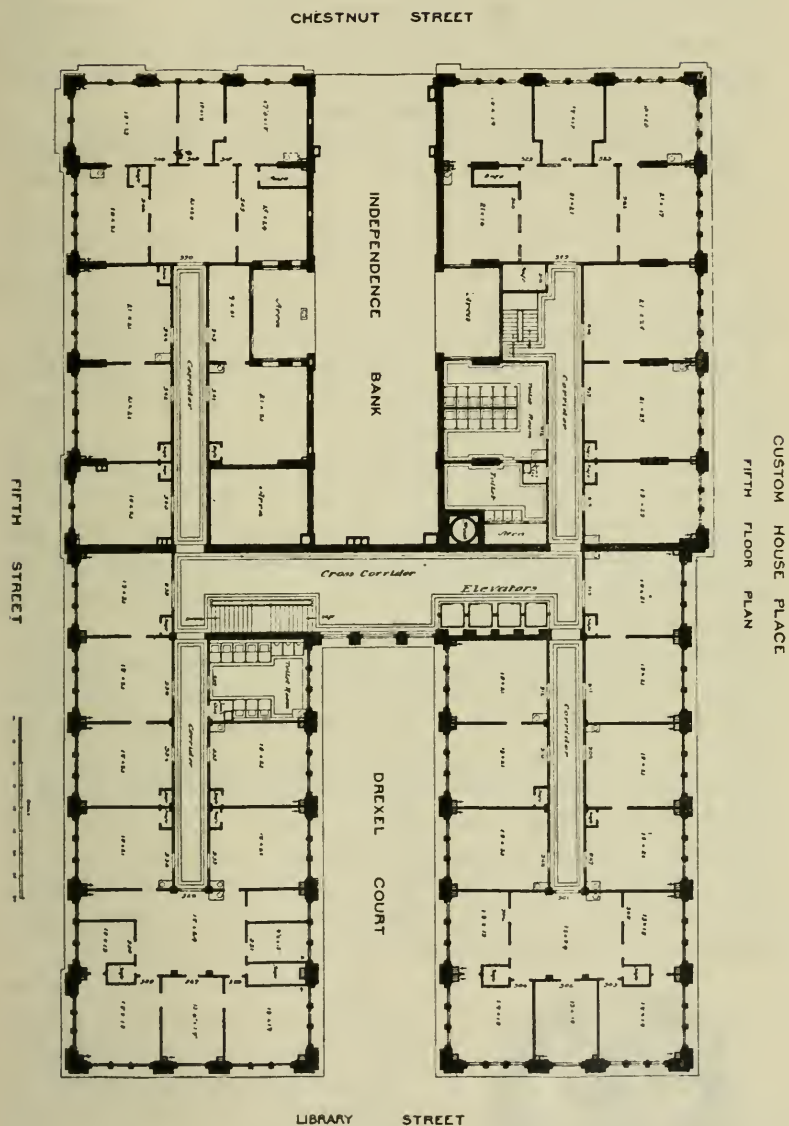


Illustration Typical Floor. (1887).

the apparatus but also the personnel of the employees, as well as the complaints of tenants and the criticisms of the owner, on his mind, and dark engine rooms with little or no ventilation, in temperatures of 130° Fahr. and over, saturated with moisture, men working at least eight hours on a shift, without relief or access to the outside air, make matters worse.

Under such conditions the expectation that efficiency can exist, or economy result, is futile. Yet this story is commonplace, the exceptions are rare.

And yet, to accomplish this offence, both against humanity and economy, deep basements, sub-basements and sub-sub-basements are constructed, at far greater expense to obtain rentable floor space than they would cost above ground.

The goal of the capitalist is net gain; net gain is at a minimum without economy; the motif of engineering is economy; the life of economy is efficiency.

However excellent the apparatus, and however expert the operator, unless both are kept in health, the result is failure. The gun is worthless without the man behind it. The first thought of the capitalist should be to keep his employees, his human machines, in prime condition. Unfortunately, both for him and for them, this is thought of least, if at all.

The first requisite, then, in designing the mechanical installation, is to give the operating engineer a chance. Put yourself in his place, and follow the golden rule. Don't expect impossibilities; then, if you don't get results, the blame is his.

The engine room should be like the deck of a man-o'-war on inspection day,—and it can be made so.

No dirt, no cripples, and bright as day.

The inspection of boiler and engine rooms here, in New York, and other cities, convinced the speaker that these things were ignored, but that the trouble could be cured.



In November, 1899, the Institution of Operating Engineers was organized, with the design of obtaining concert of action, not only among the operating engineers, but with them also among the designers, capitalists and owners. The effort

has been crowned with success, so far as the engineers were concerned; but I regret to add that the capitalists and owners have given it no encouragement.

It is not my purpose to go into the details of the manifold specialties or methods of design, which go to make up the complex organism under consideration,—but simply to give a few historical facts, so that we may trace the progress made and give some points which may be of service.

CONSTRUCTION.

The primary requisites in the design and construction of a community building are that they should be not only fireproof, but also that all the apparatus serving the tenants should be so arranged as to allow of the most radical change in the interior arrangements.

One, if not the first, example aiming at these results, was the Pennsylvania Railroad Terminal Station and offices, designed by the late Wilson Bros. & Co., and completed 1878 to 1880.

This building had (except for the outside walls, which were of brick masonry), an interior framework of steel construction, with concrete floors on terra-cotta and brick arches, and with terra-cotta partitions, but no particular attention was paid to the arrangement of the service apparatus to allow of change of partitions.

In the Drexel Building (1886-1888) the same motif of construction was followed, except that the entire frame was steel, with the requisites of arranging and providing for modifications of partitions. That this was a wise provision has been demonstrated by the fact that at the present time the number of offices has been doubled without structural changes, except as to partitions.

The next modification was the introduction of the now well-known curtain wall construction.

About the year 1888-89, Mr. Frank Furness suggested a modification in the construction of concrete floors, by utilizing a reinforcement of steel rods so disposed as to obtain the full value of the compressive strength of the concrete in cross-strain, at once not only reducing the cubic contents or unpro-

ductive space occupied by the floor construction but also very materially reducing the cost.

This was not, however, the first time that steel reinforcement was attempted since the late Dr. Ludwig Y. Filbert introduced steel members in the construction of cement pavements as early as 1876.

The early attempts were not always attended with success, as the laws which govern the construction were not fully known until the present time, when, as you know, we are as well, and



The Drexel Office Building, Philadelphia.

better informed probably to-day of the laws which should govern the concrete construction as with those on which to design metallic, timber or masonry construction.

So that the construction of the modern office building, except such glass, wood or other materials as may be necessary for decoration and comfort is *par excellence*, reinforced concrete, or what is sometimes called Concrete Steel.

In the present state of the art all combustible trimmings can be supplanted by fireproof materials, so that fireproof floor coverings, doors, window frames and mullions, as well as casings.

etc., can be constructed as easily as of wood, the skylights and the upper sash of the windows may be glazed with wire glass, and at a cost, probably not much more than if constructed by present methods.

By such construction the devastation caused by such fires as destroyed Chicago, Boston, Baltimore and San Francisco would have been impossible.

The earthquake and fire at San Francisco, which happened after this discussion was read but before going to press, emphasizes the value of the methods of construction proposed.

CONDUITS.

Conduits for all the probable electric lighting, power, telegraph, telephone and bell circuits should be provided and constructed with the buildings, arranged to serve any arrangement of partitions, and with connection for either aerial or underground mains.

Provision should also be made for local central stations and switchboards.

LETTER DROPS.

Letter drops should be located at convenient points on each floor, and if the building is extensive, a sub-Post Office should be centrally located, with pneumatic conduits for collecting the mail.

MECHANICAL INSTALLATION.

As it is necessary, except in the tropics, to heat all our community buildings, and as steam is the most flexible vehicle for the purpose, since by its use we can reclaim and use approximately 70% of the heat units in the combustible, and by judicious installation and operation reduce the power required to a by-product—we may consider that steam is an essential.

BOILERS.

Going back again to the Drexel building, put into commission November, 1888, and starting with the boilers:

These were four in number, internally fired "Galloway," with

the style of setting afterwards adopted. These boilers answered their purpose with economy, as operated, until the load demanded by sub-division of offices was so increased that not only were they run at a financial loss but their maximum capacity was exceeded. In 1903 these boilers were removed, and Edgemoore Water Tube Boilers, with four times the capacity of the original installation were substituted.

I am advised that the coal saving realized during the first year of the new plant, over that for the last year of the old plant, amounted to over 35%, and by substituting buckwheat for pea coal a net saving was obtained of one-half of the cost, showing approximately the saving obtained by ample boiler capacity with maximum grate surface over a limited capacity with minimum grate surface.

In this conjunction the installation of not only ample but seemingly excessive boiler capacity is advised.

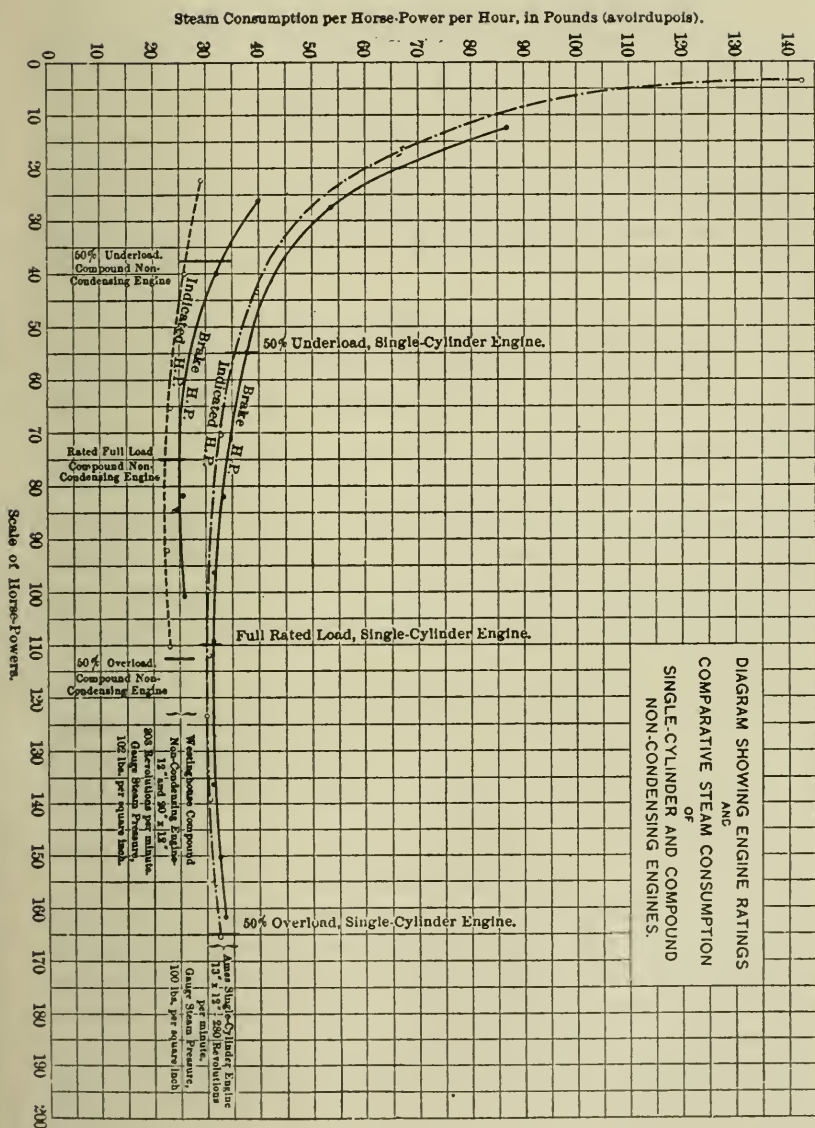
PRIME MOVERS.

The original electrical installation in the Drexel Building included two horizontal simple Armington & Sims engines of fifty H. P. each and one 100 H. P., operated by 100 lbs. steam pressure, belt-connected to four Edison, compound, direct-current generators.

These engines were operated at their nominal load (one-quarter cut off, 100 lbs. pressure), until 1900, when generators of 50% greater capacity were substituted for the original generators and operated by them.

In this connection your attention to the steam consumption on the load diagrams showing that with a variable load (such as we have on an engine serving directly the lights and power), there is a decided advantage in proportioning the engine to drive the maximum at about one-half cut-off. The diagram shows, in a variation from 25% to 150% of the rated load of the engine at one-quarter cut-off, a variation of less than 10% above the point of minimum steam consumption.

Mr. Westinghouse appreciated these facts, for the market rating of the Westinghouse engine is at the maximum load and the lowest steam consumption or proper rating is at about 70% of the maximum load.



In 1903, after a run of fifteen years, the engines at the Drexel Building were as good as new and were replaced by other engines (Harrisburg) of a total of 450 H. P., *i. e.*, 300 H. P. greater capacity, and direct-connected to the generators.

The earlier installations adopted high-speed single-cylinder engines, using steam at about 100 lbs. pressure.

Later, compound non-condensing engines were utilized, and in some plants operated with steam at 150 lbs. pressure. Whether this last innovation is an improvement remains to be proved, the question being whether or not the expense for attention and repairs is more or less than the saving in the coal pile.

In the United Gas Improvement Co.'s Office Building, gas engines were installed as the prime movers. They operated three (3) generators, in connection with an electric storage battery.

It would be interesting to know the practical results of this plant from the owners and operators.

For one thing the speaker can testify, that when the storage battery losses were *not considered*, it reduced the cost of operating the small units, such as house pumps, sewage pumps and boiler-feed pumps, to at least one-third of that incurred by the use of steam.

However advantageous such a plant may be, at the proper cost of gas for power, the advice to instal a duplicate steam driven engine (which, used during the heating season, would have made a material saving in operating expenses) should not have been disregarded.

The prime movers should be as economical of steam consumption as the cost of the total installation will warrant.

If, during the heating period the exhaust steam is first utilized in heating the building and afterward passed through the hot water generators before being returned to the boilers, an appreciable vacuum can be obtained and economy will result. This was done in 1887 at the Drexel Office Building.

In practice the elevators of an office building use the major amount of steam, and when at the same time the electrical demands are at the maximum, it often happens that there is more steam used for power than is required for heating, and the resultant exhaust is wasted.

It has been sought to prevent this loss by operating the electric generators beyond the immediate demand and storing the surplus to be used when the exhaust from the elevator service would be sufficient to heat the building.

The first cost of such an installation, together with the expense of operating and maintenance, however, has proved this method to be uneconomical.

If, however, the spare engine, always provided in a well-designed plant, be direct-connected to an air compressor, and the air stored; the air could be used as a substitute for steam in the engines driving the electric generator or in air motors, during such times as the steam would otherwise be wasted.

The exhaust from the engines using compressed air and the air motors can be used to refrigerate the water for drinking as well as to cool the air supplied in the ventilating system.

In the past the great difficulty has been that, in using compressed air, ice forms in the valve chest and in the exhaust, from condensation of the moisture in the free air.

The speaker has overcome this difficulty, at merely the cost of handling materials. It will, therefore, be seen that the cost of the apparatus for the storage of power is reduced to the minimum, *i. e.*, the cost of steel storage tanks with their incidental valves and regulating apparatus, and that the loss from the cost of production is the fraction of an additional power unit. The expense of compression can be charged against the additional useful result.

The speaker would fully endorse the now common practice of operating all the small power units with electricity.

FIRE PROTECTION.

Although it is presupposed that the buildings are fireproof, yet the trimmings, the furniture and the documentary contents are either inflammable or may be injured by fire or its antidotes.

It is therefore necessary that the antidotes be administered so judiciously that "the punishment will fit the crime," and by preventive measures reduce the crime to an insignificant misdemeanor.

As heretofore noted, at the Drexel Building, in 1886, there was designed and, in 1888, put into practice all the apparatus then known to the art.

In the Office Building of the United Gas Improvement Co. (1898), having the then advantage of the electric storage battery, an electrically-driven pump was installed by which water at a pressure of over 100 lbs. per square inch could be turned into the fire protection service in less than two minutes of the receipt of an alarm. In addition to the nozzles and hose on each floor, nozzles and hose were located on the roof.

These high-pressure water-service pipes for fire protection were, in addition to the storage-water supply in the attic, also provided with an inlet nozzle in the street to which the Municipal Fire Protection Service could be attached.

WATER SUPPLY.

As the municipal water supply is rarely under sufficient pressure to supply our tall buildings, it is necessary to install a water pumping plant and to insure economy in operation and comfort in administration, ample reservoir capacity at such elevation as will serve the building by gravity.

Multiple-plunger pumps, driven by direct-connected motors, are best adapted for this service.

The water used for sewage disposal makes the greatest demand upon this service, and can generally be obtained from the ground under the site of the building, from driven wells at no great depth.

By the utilization of this water (which, although generally, in large cities, is unfit for drinking, is perfectly clear and useful as a sewage carrier), the water rents can be reduced to a minimum.

This water, being quite cool, can also be utilized in refrigerating the air for ventilation by passing it, before delivering it to the storage tank, through the coils used in winter for tempering the air supplied for ventilation.

HOT WATER SUPPLY.

If my memory serves me correctly, the supply of hot water to individual offices was first installed in the Professional Building.

This water was distributed on the double supply system, with the result that water at 200° Fahr. was immediately on tap at instant demand.

ELEVATOR SERVICE.

The modern passenger elevator service, suitable for office buildings can be traced to 1880, when high-speed hydraulic elevators were installed in the Pennsylvania Railroad Terminal Station, and elevators with a maximum speed of 700 feet per minute were successfully operated. So that in 1886-87, when the Drexel Building was designed, this problem had been solved.

From time to time improvements have been made in the apparatus as regards safety, comfort and economical operation.

Prior to 1887, the simple duplex steam-driven pump, was used to operate the hydraulic elevators. The apparatus in the Drexel Building was furnished with compound duplex pumps. Since that time, high-duty compound rotary pumps have been introduced.

Electrically-driven elevators have also been extensively introduced, initiated, I think, by Mr. Frank J. Sprague.

These electrical machines are subdivided into the drum type and what is known as the Sprague screw type. An electrically-driven pump was found, in some instances, advantageous to operate hydraulic machines.

Water and electricity superseded the old-style steam-driven drum machines and made possible the nice adjustments, in running, so necessary in the office building.

Many varieties of the hydraulic apparatus, more or less perfect and adapted to the different conditions obtaining in the various buildings, were designed from time to time. At first, the vertical and horizontal cylinder machines, pulling or pushing the piston which connected with the hoisting ropes, over multiplying sheaves, were presented to the designing engineer.

About 1898, the direct hydraulic-plunger machine (which had previously been installed for lifts not exceeding fifty feet), was adapted for use in high buildings, and, for lifts not exceeding 200 feet, have become quite popular.

The Sprague electric screw machine, after the general design of the hydraulic cylinder apparatus, with the endless screw and nut operating the multiplying gear of the rope hoist, was invented, and put on the market about 1896.

Such elevators were installed in the U. G. I. Office Building

and are giving satisfaction, both as to the consumption of power and for wear and tear. The screws, so much feared, have shown at the U. G. I. Co., an average life of four years.

The drum electric machines cannot be classed as applicable to the co-called high building, as at present understood.

In safety appliances, some improvements have been made in automatic apparatus. These improvements, together with the Cruikshank device (first utilized about 1900 to 1901) have practically supplanted the one-time supposed indispensable air-cushion.

Pneumatic devices for closing hatch doors, electric signals, and a host of minor conveniences have been invented and utilized in the past ten to fifteen years,—some wise, some otherwise.

The elevator apparatus has now reached such perfection, that the percentage of accident is less than is recorded for any other method of transportation, and engineers are building speed elevators for office buildings of 500 feet and over.

ELECTRICAL SERVICE.

The principal uses of electricity in the Community Building are for communication, illumination and power.

In the year 1845, Professor Henry, of the Smithsonian Institute, illuminated his home with direct electric current, from a static battery, passing through a filament in vacuum. From this we have the incandescent lamp of commerce, without which to-day we would be lost.

In 1870, Bulwer-Lytton wrote "The Coming Race," in which he described what we now have and that which is to come.

In 1876, John Wanamaker installed a Jablochkoff candle in front of the entrance to his Grand Depot—one of the first examples of commercial electric lighting.

The Jablochkoff candle was an arc lamp, served with high-tension dynamic electricity.

About 1881, simultaneously, or nearly so, Moses G. Farmer, Hiram Maxim and Thomas A. Edison, produced and placed in the market the commercial incandescent electric lamp served by dynamic electricity.



Office Building of the United Gas Improvement Company, Philadelphia.

These early lamps were run only in "series" and utilized current of about fifty volts pressure.

In 1884, or 1886, Mr. Edison invented and marketed a lamp which could be run in multiple and with current at a pressure of about 110 volts.

It was not, however, until 1898, when in Philadelphia, a plant was designed and installed by the speaker which successfully utilized incandescent lamps in multiple at an electrical pressure of 220 volts.

This innovation reduced the conductors to one-quarter that required by the 110 volt current and to one-eighth that required by the fifty volt lamp in multiple.

Philadelphia can therefore justly claim the credit for this advance as developed and perfected at the Office Building of the United Gas Improvement Co., for previously a noted New York engineer had unsuccessfully attempted to utilize this voltage in the R. G. Dun Building, and also in the Lorraine Hotel, New York City, and he says he "thought the wiring millenium was arriving," but he goes further and describes his troubles and states "that no one should adopt this voltage, etc., etc.*"

ELECTRIC GENERATORS.

The electric generators installed in the Drexel Building (1888) were four in number at forty k.w. each, belt driven from steam engines, direct current, bi-polar compound wound to compensate from 110 to 118 volts pressure.

They were of the first lot of compound wound machines made by the Edison Company. The earlier generators were either shunt or series wound, with, I think, one exception in the horizontal bi-polar, compound, dynamo made by the Sawyer-Mann Company.

One of these generators was installed as early as 1885 in the store of Hood, Bonbright & Co., Twelfth and Market Streets, Philadelphia. The regulation of this machine was perfect. I pulled the main switch with the generators running under full load and without observable change in the potential of the pilot lamp on the machine.

*See Note A, and Transactions of Am. Soc. of Civil Engineers, Vol. xlviii, pp. 34, 56, 57 and 58.

The Edison bi-polar generators in the Drexel Building were operated until the year 1900, or about twelve years, when they were replaced by Westinghouse generators with a 50% greater capacity. If my recollection serves me, but one armature on the old machine was replaced, and at the end of the twelve years the apparatus was in excellent condition, and, except for the wear on the commutators, had all the outward appearance of youth.

The generators in the U. G. I. Office Building (1898) were multi-polar, direct connected to gas engines, all the other apparatus in the building driven by electricity from a storage battery, no steam-driven machinery being installed.

ELECTRIC MOTORS.

The electric motors driving the ventilating fans in the Drexel Building were two-pole, of Sprague design and after nineteen years of continuous running, ten hours per day, during office hours, are still in service and excellent condition.

I will not attempt to further discuss this subject, the ramifications of the motor field for work and the variety and designs are so great that time would fail.

ELECTRICAL DISTRIBUTION.

The distribution service board originally installed in the Drexel Building was a plug board. My recollections of this provoke a smile.

Subsequently the board was substituted by one of modern design.

The electrical distribution was so sub-divided as to give the engineer in his office complete and individual control in detail of the entire building.

NOTE A.*

THE ELECTRICAL PLANT IN THE OFFICES OF THE UNITED GAS IMPROVEMENT COMPANY.

In sharp contrast with the electrical plant of the Drexel Building, the electrical plant of the office building of the United Gas Improvement Company, designed in 1898, utilized successfully direct current electricity at 220 volts, distributed on a two-wire system. This voltage had previously been attempted in New York. In criticizing the use of this voltage (1892), the following remarks were made:

"The usual practice is as the author says, to use a two-wire system at 110 to 120 volts," but he goes on to advocate the use of high-tension current at 220 volts. The speaker designed the R. G. Dun Building for a 220 volt current, and thought the wiring millenium was arriving.

"The reduction in the cost of copper was tempting, the lamps appeared to be of about the same price, and it seemed to be advantageous to distribute both the motor load and the electric lighting load on the same basis from a two-wire switchboard. There was trouble with the distribution boxes, however, because a fuse letting go at the bottom of it would burn out the whole line. The lamps were inefficient, and, although they are somewhat improved now, they are still not as efficient by nearly twenty per cent. as the lamps at 110 to 120 volts; nor do they have so long a life, on all of which grounds the speaker (Mr. Bolton) bases his opinion that no one should adopt the higher voltage without serious consideration.

"The 220 volt system was also installed in the Lorraine Hotel. The tenants, assuming that the system was about the same as they had usually dealt with elsewhere, attached hair-curling tongs, portable lamps, fans, and all kinds of electrical notions, the result being that the fuses were constantly blowing out, which kept the chief engineer busy most of his time repairing breaks and grounds."

The criticism was answered as follows:

"The experience noted with the 220 volt system is certainly very unsatisfactory; the writer would imagine that the critic would have such experience in a hotel. The trouble mentioned with reference to the distribution boxes has not come within the writer's experience, but, from what has been stated, the further adoption of this voltage should be carefully considered."

"The many advantages to be gained in using this voltage should not condemn it because first attempts may show defects of installation. In the writer's practice, and from inquiry among those since using this voltage in Philadelphia office buildings, the troubles complained of have not been experienced.

"The higher voltage requires better installation and greater care in construction, and the fuses in the junction boxes should be arranged so that if one should burn out, it will not burn out the others.

"The lamps for the 220 volt current have been much improved, and no doubt will be improved further, as the 110 volt lamps have been."

"The experience in Philadelphia, with the practical use of this voltage, has been so successful that its further adoption is warranted, and, in the writer's opinion, the millenium should not be regarded as impossible because of first failure."

Extracts Am. Soc. C. E., Vol. xviii, "Mechanical Installation of Office Buildings."

(To be concluded.)

Mining and Metallurgical Section.

The Petroleum of North America. A Comparison of the Character of Those of the Older and Newer Fields *

BY CLIFFORD RICHARDSON.

Among the native bitumens those are to be classified as petroleum which are liquid at ordinary temperatures. Such a classification includes the more rarely occurring naphthas and the heavier malthas, the latter dense liquids flowing only very slowly at ordinary temperatures and gradually grading into the solid bitumens.

Petroleum is very widely distributed over the continent of North America and the adjacent islands. It is found in Alaska, in the Provinces of British Columbia, Alberta, Athabasca, Assiniboia, Ontario, Quebec, New Brunswick, Nova Scotia and Cape Breton of the Dominion of Canada, and in especially large amounts in Lambton and Essex counties in Ontario. It is well distributed throughout the United States from the Atlantic to the Pacific Coasts, forming numerous fields known as the Appalachian, owing to the fact that it follows the trend of the Appalachian Mountains, and including the States of New York, Pennsylvania, West Virginia, South-eastern Ohio and parts of Kentucky and Tennessee; the Ohio-Indiana, the Kansas, including portions of the Indian and Oklahoma Territories; the Texas and Louisiana; the Colorado; the Wyoming; and, on the Pacific Coast, the California fields of the Central Valley and of the immediate coast in Santa Barbara, Ventura, Los Angeles and Orange Counties. Petroleum, although undeveloped as a commercial product, is known in Mexico along the coast of the Gulf of Mexico, and it occurs in several localities in the Island of Cuba.

DEVELOPMENT OF PETROLEUM AS AN INDUSTRIAL PRODUCT IN NORTH AMERICA.

Although petroleum had been collected in small amounts for many years previously its production on an industrial scale may be said to date from the completion of the first well, which was

*Read by title.

sunk for the purpose of obtaining oil, at Titusville, Pa., in 1859.* In 1861, the petroleum obtained from this field exceeded two million barrels, of forty-two gallons, the output gradually increasing in Pennsylvania and New York until, in 1882, it was more than thirty million barrels.† From that time on the production has varied in these States, reaching thirty-three million barrels in 1891, and then decreasing until, 1904, when only a little over twelve million barrels was the output.

The total output of the Pennsylvania and New York fields has, therefore, decreased markedly in the last ten years, but that of West Virginia and South-eastern Ohio, which may be regarded as part of the same field, since the source and character of the oil is much the same, has increased to such an extent, from 492,578 barrels in 1890 to 12,644,686 barrels in 1904, as to make the product of the entire Appalachian field at the present time nearly as large as it was some years ago, the total production in 1904 being 31,408,567 as compared to 36,295,433 barrels, the largest output, produced in 1900, its value being greater than that of any other field.

As early as 1862, crude petroleum was produced to a small extent in the Province of Ontario, Canada, the output increasing in subsequent years until it exceeded one million barrels in 1894. From that date it has fallen off until ten years later, 1904, it was something less than half a million barrels.

In 1885, the petroleum of the Ohio-Indiana field became a factor in the North American supply, reaching over six thousand barrels in that year, and increasing to 24,689,184 barrels in the two States in 1904, making this field the third in its output and second in value of its product. Within recent years the production of the State of Indiana has increased largely, while that of Ohio has fallen off considerably.

The existence of oil in California was known as far back as the seventh decade of the last century, attention having been drawn to it by the State Geologist in 1865. It did not become of industrial importance until many years later, the output not exceeding 100,000 barrels until 1882, and 1,000,000 barrels only

*Petroleum and Its Products, 10th Census, S. F. Peckham, 1880, p. 11.

†This and the following data in regard to production are from Mineral Resources, U. S. Geological Survey, Washington, D. C., 1881-1904.

in 1895. In 1904 it had reached the astonishing figure of 29,649,434 barrels, and the State ranked as first in the amount of petroleum which it produced and second as a field, although not first in the value of its product owing to its inferior character.

Colorado first figures as a producing State in any amount in 1887, with less than 100,000 barrels. Since that time the output has reached over 800,000 barrels, in 1892, and has fallen off, in 1904, to 501,763 barrels.

The petroleum industry of Kansas and the adjacent Territories is the development of the last few years. In 1900, less than 75,000 barrels were produced, while in 1904, more than five and a-half million barrels were obtained in that State and the adjacent Territories.

Texas, the second largest producing State in 1904 and the fourth as a field, turned out over half a million barrels in 1901, and in 1904 reached 22,241,413 barrels.

The output in barrels of the various fields, which have been mentioned and the percentage of the total product in the years 1899 and 1904 are given in the following table:*

PRODUCTION OF PETROLEUM IN THE UNITED STATES, 1899 AND 1904.
BY FIELDS.

(Barrels of 42 Gallons.)			
1899.		1904.	
Barrels.	Percentage.	Barrels.	Percentage.
Appalachian	33,068,356	31,408,567	26.830
Ohio and Indiana.....	20,225,356	24,689,184	21.091
California	2,642,095	29,649,434	25.328
Colorado	390,278	501,763	.429
Kansas, Indian and Oklahoma Terri's.	69,700*	5,617,527	4.799
Texas	669,013	22,241,413	18.999
Louisiana .....	.....	2,941,419†	2.513
Wyoming	5,560	11,542	.009
Other	492	2,572	.002
57,070,850‡		117,063,421	100.000

*Only from the Kansas field.

*Mineral Resources, U. S. Geol. Survey, 1904.

†In addition to this quantity, 3,670,000 barrels were produced in Louisiana and unsold at close of 1904.

‡In addition to this quantity 13,578 barrels were produced in Kentucky and Tennessee in 1899, for which, as none was sold or used, no value could be given.

RANK OF PETROLEUM-PRODUCING FIELDS, ACCORDING TO THE VALUE OF THE
PRODUCT, IN 1904.

Field.	Rank.	Percentage	Value.
Appalachian	1	41.12	\$41,602,798
Ohio and Indiana.....	2	35.55	35,966,189
California	3	8.17	8,265,434
Texas	4	8.06	8,156,220
Kansas, Indian and Oklahoma Territories	5	5.39	5,447,622
Louisiana	6	1.06	1,068,605
Colorado	7	.57	578,035
Wyoming	8	.08	80,794
Michigan and Missouri.....	9		4,769
		100.00	101,170,466

It will be noted from the above table that there has been a considerable rearrangement, in five years, in the relative amount of petroleum produced in the different fields, while the total production has more than doubled in the same period. The paraffine oils, however, those from the Appalachian, Ohio-Indiana, Colorado and Kansas fields, still form more than one-half of the output.

The rank of the different States as producers and the percentage of production in 1904 was:

RANK OF PETROLEUM-PRODUCING STATES AND TERRITORIES ACCORDING TO
PRODUCTION IN 1904.

	Rank.	Percentage.	Barrels.
California	1	25.33	29,649,434
Texas	2	19.00	22,241,413
Ohio	3	16.13	18,876,631
West Virginia	4	10.80	12,644,686
Indiana	5	9.69	11,339,124
Pennsylvania	6	9.65	11,300,792
Kansas	7	3.63	4,250,779
Louisiana	8	2.51	2,941,419
Indian and Oklahoma Territories.	9	1.17	1,366,784
Kentucky and Tennessee.....	10	.85	998,284
New York	11	.80	938,234
Colorado	12	.43	501,763
Wyoming	13	} .01	11,542
Missouri	} 14		} 2,572
Michigan			
		100.00	117,063,421

In value of production the States ranked as follows:

RANK OF PETROLEUM-PRODUCING STATES AND TERRITORIES ACCORDING TO
THE VALUE OF THE PRODUCT, IN 1904.

State.	Rank.	Percentage.	Value.
Ohio	1	23.46	\$23,730,515
West Virginia	2	20.35	20,583,781
Pennsylvania	3	18.29	18,507,103
Indiana	4	12.09	12,235,674
California	5	8.17	8,265,434
Texas	6	8.06	8,156,220
Kansas, Indian and Oklahoma Territories	7	5.39	5,447,622
New York	8	1.51	1,526,976
Louisiana	9	1.06	1,068,605
Kentucky and Tennessee.....	10	.97	984,938
Colorado	11	.57	578,035
Wyoming	12	.08	80,794
Michigan and Missouri.....	13	.08	4,769
		100.00	\$101,170,466

CHARACTER OF THE PETROLEUMS OF NORTH AMERICA.

Petroleum may be differentiated by their physical characteristics and their proximate chemical composition. They are mixtures of several series of hydrocarbons and their derivatives, in variable proportions and usually several and rarely all of the different series.

The determination of the proximate composition of crude petroleum has been hitherto attempted almost exclusively by distillation and has, therefore, been confined to the separation of the more volatile components, although by means of distillation in vacuo hydrocarbons of very high boiling points, over 350° at 50 mm. pressure have been separated, but not as simple substances. More recently the writer has undertaken the study of the residuals left after such distillation, by means of solvents, with results of considerable interest.

The nature of the proximate constituents which have been referred to can be most readily demonstrated by consideration of the components of the oils from the various individual fields the production of which has been described.

APPALACHIAN FIELD.

The petroleums of the Appalachian field, which includes Western New York, Pennsylvania, West Virginia, South-eastern Ohio and Eastern Kentucky, are found in the strata of sand and pebble conglomerate from one hundred feet above the Pittsburg coal in the Carboniferous to nearly four thousand feet below it in the lower Devonian.* They consist fundamentally of one series of hydrocarbons, C_nH_{2n-2} , and are therefore, known as paraffine petroleums, although series less rich in hydrogen are present. The crude oil has in general a peculiar greenish color by reflected light and a deep reddish-brown color by transmitted light. In exceptional cases light colored oils are found, not darker than yellow or amber, which must have resulted from a selective filtration through strata which permit of the passage of only the less viscous hydrocarbons. The density of the average Appalachian petroleum, as it occurs in the pipe line runs to the refineries, is from .80 to .82, 45.0 to 40.7° B., a Pennsylvania pipe line oil examined by the writer in 1900 having a density of .8014, 44.7° B., but oil of as low a density as .771, 51.6° B., occurs in Washington County, Pennsylvania, higher than the average in the Berea grit in Ohio, and as high as .850, 33.7 B., in West Virginia and Kentucky, some of the West Virginia oils being found to be extremely desirable lubricants after filtration and without distillation.

The examination of the crude petroleum of the Appalachian field has attracted the attention of numerous investigators, from the time of C. M. Warren, 1865, to the present. The results enable us to form a satisfactory idea of the proximate composition and character of this oil. Oils from different parts of the field have shown on examination in the writer's laboratory the following characteristics:

	Ohio. Noble Co.	Pennsylvania. Pipe line.	Kentucky. Sunnyside.
Specific gravity, 25/25°.....	.8293	.8014	.8426
Flash	Ord.	Ord.	Ord.
Viscosity, Pa. R. R. pipette.....	42''	37''	.....

*Mineral Resources, U. S. Geol. Survey, F. H. Oliphant, 1903, p. 650.

Volatility in Open Dish.

105°, 7 hours	41.2 %	47.3 %	40.7 %
160°, 7 hours	43.0	58.0	44.5
200°, 7 hours	59.0	68.0	58.0
<i>To constant weight:</i>			
105°, 42 hours	48.7	58.7	70.6
160°, 70 hours	61.0	71.8*	73.8
200°, 49 hours	75.0	84.0	....

*49 hours.

Viscosity of Residue.

7 hours at 200°	Soft.	Soft.	Soft.
49 hours at 200°	Brittle.	Brittle.	....
Penetration	Pitch.	Pitch.	....

Distillation Engler's Flasks.

Distillation begins	85°	80°	67°
Below 150°	23.0 %	21.0 %	19.0 %
150-300°	21.0	41.0	37.0
300-350°	21.0	14.0	20.0
350-400°	27.0	23.0	20.0
Loss on acid treatment (150-300° frac- tion)	5.0	1.8	....
Percentage of acid used	2.5	2.0	....

Specific Gravity and Refractive Index.

	Sp.Gr.	Ref.Ind.	Sp.Gr.	Ref.Ind.	Sp.Gr.	Ref.Ind.
	Ohio.		Pennsylvania.		Kentucky.	
Below 150° ..	.7297	1.412	.7188	1.415	....	....
150-300°	.8013	1.442	.7984	1.437	....	....
300-350°	.8404	1.468	.8338	1.462	....	....
350-400°	.8643	1.481	Paraffine.	1.470	....	....
<i>After acid treatment:</i>						
150-300°	.8006	1.443	.7791	1.438		

Distillation in Vacuo.

Atmosph. pressure:

120-170°	.7375	1.422
<i>22 mm.</i>		
90-120°	.7796	1.438
120-150°	.8267	1.451
150-180°	.8305	1.464
180-230°	.8494	1.474
230-290°	.8746	1.489
290-320°	.8863	1.504

Distillation of a Pennsylvania petroleum on a larger scale, carried on by Mabery, give the following results:

Fraction.	Per cent.
50-150°	21
150-200°	11
200-250°	11
250-300°	13
Over 300°	42

The ultimate composition of the crude oil and of a residuum obtained by spontaneous evaporation of the oil in a current of air he found to be:*

	Crude.	Residue 33.33
Specific Gravity.....	.830	.862
Symbol	C_nH_{2n}	C_nH_{2n-2}
Carbon	85.51 %	86.16 %
Hydrogen	14.18	13.69

From the preceding data it is apparent that the petroleum of the Appalachian field contain a high percentage of constituents which are volatile or distill at a comparatively low temperature and which are of a low density and suitable for the preparation of naphtha and illuminating oils.

A determination of the ultimate composition of these oils shows that they consist essentially of 85.5 to 86.0 per cent. of carbon, 14.2 to 13.5 per cent. of hydrogen and a few hundredths of one per cent. of sulphur and nitrogen.

The distillates of the crude petroleum have been examined with great care by Young, Mabery and others, with to the determination of their proximate composition. Mabery has found that the hydrocarbons of the C_nH_{2n+2} series are present, with a few exceptions, from butane, boiling at -10° , to one of the formulæ $C_{35}H_{72}$, and that probably other solid paraffines of higher molecular weight are present the formulæ of which it is impossible to determine with our present methods. He also finds liquid saturated hydrocarbons of the C_nH_{2n} series, from $C_{21}H_{42}$ to $C_{26}H_{52}$, and others of possibly higher molecular weight, while he has separated liquid saturated hydrocarbons of the C_nH_{2n-2} series containing twenty-seven and twenty-eight atoms of carbon.†

Young has isolated from the lighter distillates of Pennsylva-

*Proc. Am. Acad. A. and Sci., 1904, 40, 347.

†Proc. Am. Acad. A. and Sci., 1902, 37, 595.

nia petroleum in a very considerable degree of purity the naphenes or monocyclic polymethylene hydrocarbons C_nH_{2n} , containing five, six and seven atoms of carbon, pentamethylene, methylpentamethylene, hexamethylene, dimethylpentamethylene and methylhexamethylene, corresponding to those found in Russian petroleum.

Both of the preceding investigators have found considerable amounts of aromatic hydrocarbons. Young finds benzol in the fraction boiling at about 65° and 66° , and toluol to a considerable extent in a higher fraction,* while other homologues have been detected by Mabery.

While unsaturated hydrocarbons are present in Pennsylvania petroleum, and are readily removed by strong sulphuric acid, there is, in the opinion of all modern investigators, no sufficient evidence that these hydrocarbons are members of the olefine series. Their actual structure has not yet been determined.

Sulphur and hydrogen derivatives of the hydrocarbons are present in but mere traces.

The following table gives the characteristics of the various saturated hydrocarbons of the C_nH_{2n+2} , C_nH_{2n} and C_nH_{2n-2} series, as described by Mabery and Young:

C_nH_{2n+2} Hydrocarbons.						
Composition.	Specific Gravity.	Ref. Index.	Boil. Point.	Pressure.	Melt. Point.	
C_4H_{10} Iso.			0°	760mm.		Mabery.
C_5H_{12} Nor.	.6250 $25/25^\circ$		36.3	"		Young.
	.6261 $0/4^\circ$					
	.6454 "					
" Iso.	.6392 "		27.95	711mm		"
C_6H_{14} Nor.	.6771 "		68.95	"		"
" Iso.	.6730 "		61.00	"		"
C_7H_{16} Nor.			98.40	"		"
" Iso.	.6969 $0/4^\circ$		90.30	"		"
C_8H_{18} Nor.	.7188 $20/20^\circ$		125.00	760mm		"
" Iso.	.7190 "		119.50	"		Mabery.
C_9H_{20} Nor.			151.00	"		"
$C_{10}H_{22}$ Nor.	.7479 "		163-164	"		"
" Iso.	.7467 "		173-174	"		"
$C_{11}H_{24}$	.7581 "		196-197	"		"
$C_{12}H_{26}$ Nor.	.7676 "		214-216	"		"
$C_{13}H_{28}$	.7834 "	1.451	226	"		"
$C_{14}H_{30}$	.7814 "	1.436	236-238	"		"
$C_{15}H_{32}$	.7896 "	1.4413	256-257	"		"
$C_{16}H_{34}$	.7911 "	1.4413	274-275	"		"
$C_{17}H_{36}$	.8000 "	1.4435	288-289	"	10	"
$C_{18}H_{38}$	.8017 "	1.440	300-301	"	20	"

*J. Chem. Soc., 1898, 73, 914 and 918.

$C_{19}H_{40}$	.8122	"	1.4522	210-212	50mm	33-34	Malbery.
$C_{21}H_{44}$				230-231	"	40-41	"
$C_{22}H_{46}$	.7796	15°		240-242	"	44	"
$C_{23}H_{48}$	.7900	60		258-261	"	45	"
$C_{24}H_{50}$	.7902	"		272-274	"	48	"
$C_{25}H_{52}$	.7941	"		280-282	"	53-54	"
$C_{26}H_{54}$	.7977	"		292-294	"	58	"
$C_{28}H_{58}$	.7945	70		310-312	"	60	"
$C_{31}H_{64}$	.7992	"		328-330	"	66	"
$C_{32}H_{66}$	.8005	75		342-345	"	68	"
$C_{34}H_{70}$	.8009	80		366-368	"	72	"
$C_{35}H_{72}$	.80052	"		380-384	"	76	"

Monocyclic Polymethylenes— C_nH_{2n} .

Compo- sition.		Specific Gravity.	Boil. Point.	Pres- sure.	
C_5H_{10} Pentamethylene		.7000	0/4°	50°	760 mm. Young.
C_4H_{12} Methylpentamethylene		.7660	"	72	" "
C_6H_{12} Hexamethylene		.7722	"	80.6	" "
C_7H_{14} Dimethylpentamethylene		.7543	20/4°	94	" "
C_7H_{14} Methylhexamethylene		.7964	"	102	" "

Hydrocarbons C_nH_{2n} .

Compo- sition.	Specific Gravity.	Refractive Index.	Boiling Point.	Pres- sure.	
$C_{21}H_{42}$	.8424	20/20°			
$C_{22}H_{44}$	.8262	"	1.454	240-242°	50 mm. Mabery.
$C_{23}H_{46}$	.8569	"	1.4714	258-260	" " "
$C_{24}H_{48}$	.8598	"	1.4726	272-274	" " "
$C_{26}H_{52}$	.8580	"	1.4725	280-282	" " "

Hydrocarbons C_nH_{2n-2} .

$C_{27}H_{52}$	.8688	20/20°	1.4722	290-294°	50 mm. Mabery.
$C_{28}H_{54}$	.8694	"	1.4800	310-312	" " "

It will be observed in the preceding tables that distillates from Pennsylvania petroleum have been obtained corresponding in composition to the presence of carbon atoms from four to thirty-five, with a few exceptions. While the lower distillates may consist of single hydrocarbons, it is impossible to believe that this is the case with the higher ones, owing to the large number of possible isomers. This, however, does not detract from the interest in the results obtained since they prove that hydrocarbons exist in petroleum of this derivation containing carbon atoms in these numbers combined with hydrogen in the proportions corresponding to the general formulæ C_nH_{2n+2} . All the members of this series containing fourteen atoms of carbon and above are solid paraffines, melting at from 10° to 60°, and Mabery has shown that these solid paraffines exist as such in the crude petroleum and are not formed as the result of

decomposition on heating, since he has isolated them from the crude oil without the aid of heat, by evaporation at ordinary temperature in a current of air, a fact which is not unexpected since they are found to separate naturally on the sucker rods of pumps in wells yielding petroleum in which the solid paraffines are present in large amounts.

The lower polymethylenes or naphthenes, C_nH_{2n} , isolated by Young, are plainly monocyclic hydrocarbons. The higher distillates, like those which occur in Russian petroleum, corresponding in composition to the same general formulæ, and containing twenty-one atoms of carbon and over are associated with C^nH_{2n+2} hydrocarbons containing the same number of carbon atoms or one or two less. They do not solidify at very low temperatures and are separated from the paraffines by freezing and filtration. From our knowledge of the hydrocarbons in asphaltic oils it would appear that they differ from them essentially, as they are much more stable, have a lower density, and, for the same refractive index, nearly double the molecular weight and a much higher boiling point:

	Paraffine petroleum*	Trinidad asphalt†	California petroleum*	California petroleum†
Density	.8598	.8690	.8808	.8654
Refractive Index.....	1.4726	1.4721	1.470	1.474
Boiling Point.....	272-274°	170-180°	175-180°	178°
Pressure	50 mm.	30 mm.	60 mm.	30 mm.
Formulæ	$C_{21}H_{42}$	$C_{12}H_{24}$	$C_{16}H_{32}$	.....

With the large number of carbon atoms which these hydrocarbons contain they must be either polycyclic or contain an elaborate side chain. In the former case the hydrogen atoms should be less than twice the number of those of carbon and in the latter the hydrocarbons should be very unstable. We have no grounds, therefore, for any conclusions as to their structure, but it is evident that they belong to a series quite different in constitution from any that have been previously studied and that they are not identified with the asphaltic hydrocarbons.

The constitution of the hydrocarbons of twenty-seven and twenty-eight atoms of carbon, corresponding to the formula C_nH_{2n-2} is equally difficult to explain. As this large number

*Mabery.

†Richardson.

of carbon atoms should correspond to the existence of at least three rings, this would not permit of the presence of hydrogen corresponding to the C_nH_{2n-2} formula. The hydrocarbons of both of these series are saturated, that is to say, are not attacked by strong sulphuric acid, and consequently there is no possibility of the existence of double bonds.

The investigations, the results of which have been just outlined, have been confined to those proximate constituents of crude Pennsylvania petroleum which are obtainable by distillation in vacuo. The residues from such distillation are extremely dense substances which cannot be further distilled without cracking and must, therefore, be studied in quite a different way.

This has been done by the writer with the aid of solvents, treatment with acid, determination of their physical properties and the amount of fixed carbon which is left on ignition in the absence of air. The ultimate composition of such a residuum has been found by the writer to be:

Carbon	87.44 %
Hydrogen	12.50
Sulphur	.60
100.54	

It will be seen that, as compared with the crude oil, there is a smaller percentage of hydrogen and a larger one of sulphur in the residuum, which would naturally be expected. On treatment with ordinary and fuming sulphuric acid, however, the hydrocarbons which are unacted upon and which form 53.3 per cent. of the residue, have the ultimate composition of the C_nH_{2n+2} series:

Carbon	84.74 %
Hydrogen	15.30
Sulphur	.21
Nitrogen	.00
100.25	

More than one-half of the dense residuum from Pennsylvania petroleum consists of paraffine hydrocarbons, largely solid paraffines at ordinary temperature.

The further characteristics of such a residuum are as follows:

Physical Properties.

Specific gravity, 25/25°	.9202
Flash	186°

Chemical Characteristics.

Loss 160°, 7 hours	5.3 %
Character of residue	Soft.

Loss 200°, 7 hours (fresh sample)	14.2 %
Character of residue	Soft.
Character of residue to constant weight	Brittle pitch.

Bitumen soluble in CS ₂ , air temperature	99.8 %
Organic matter insoluble	.2
Inorganic or mineral matter	.0
	100.0

Bitumen insoluble in 88° B. naphtha, air temperature. Pitch	4.3 %
Per cent. of soluble bitumen removed by H ₂ SO ₄	21.9
Per cent. of total bitumen as saturated hydrocarbons	74.8

Per cent. of solid paraffines	11.0 %
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Fixed carbon	3.0 %
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It appears that the residue contains a certain amount of hydrocarbons or their derivatives which are volatile at 205° when exposed to this temperature in an open dish, and that if this exposure is continued for a certain length of time a brittle pitch is left. This pitch is no doubt formed by condensation due to the severe treatment to which the oil has been subjected and is not present as such in the crude petroleum. The residue carries a considerable percentage of solid paraffines which can be separated by the Holde method, as modified by the writer.* The amount, at least in industrial products, would depend upon the manner in which the distillation has been carried out. If a plentiful steam agitation is employed a part of the paraffine scale will be carried over into the distillate. The amount of fixed carbon obtained on ignition is very small, only three percent., a characteristic which differentiates the residuums from paraffine petroleum from those obtained from the asphaltic oils of California, as will appear later.

*J. Soc. Chem. Ind., 1902, 21, 690.

It is also worthy of note that of the hydrocarbons present but from ten to twenty-two per cent. are in a form involving a double bond, since this is the amount removed from a naphtha solution of the residue on treatment with strong sulphuric acid.

A certain light is thrown, therefore, on the characteristics of the denser portion of the Appalachian petroleum by means of these determinations.

In résumé, it appears from the preceding data, that the paraffine petroleum of the Appalachian field consist of small amounts of monocyclic, aromatic and polymethylene hydrocarbons, which have been separated in such a degree of purity as to be identified definitely; of minute traces of sulphur and nitrogen compounds and, predominatingly, of paraffine hydrocarbons from isobutane, C_4H_{12} to $C_{35}H_{72}$, the members above 14 being solids at ordinary temperatures. Polycyclic hydrocarbons of the C_nH_{2n} series are also present in very considerable amounts from C_{21} to C_{26} , the constitution of which is not understood but which are quite different from the hydrocarbons of the same relation of carbon and hydrogen found in asphaltic oils, and have no relation to the ethylene or olefine series. Polycyclic hydrocarbons of the C_nH_{2n-2} series are also present in the fractions boiling above 290° , at 50 mm. The latter two classes of hydrocarbons are worthy of careful study. They are saturated, in that they are not acted upon by strong sulphuric acid, and are all sharply differentiated from the hydrocarbons of the asphaltic petroleum of California by their physical properties. The opportunities for investigation in this direction are large but the problem is an extremely difficult one.

(To be concluded.)

CHEMICAL SECTION.

Note on the Examination of Maple Product—The
Lead Value.*

BY ALBERT P. SY.

The usual determinations made in the examination of maple products are: moisture, specific gravity, total solids, ash, sucrose, reducing sugars (dextrose) and malic acid. Various investigators have made a special study of one or other of these constants. Jones, of the Vermont Agricultural Experiment Station, and Hortvet, of the Minnesota Dairy and Food Department, have studied in detail the ash of maple products. Not only have they established a figure for the minimum quantity of ash which should be found in a pure product, but they have determined the total alkalinity of the ash, alkalinity of the water soluble portion, alkalinity of the insoluble part, phenol phthalein alkalinity, methyl orange alkalinity, and also ratio of water soluble to insoluble.

Other investigators have paid more attention to the malic acid in maple products. The usual method for the quantitative determination of malic acid is the calcium chloride precipitation; the precipitated calcium malate is ignited to calcium carbonate and the latter determined by titration. Hortvet determines the bulk of a "lead sub-acetate precipitate" by a centrifugal method, and this gives an indication as to the amount of malic acid present, since sub-acetate of lead precipitates principally the malic acid. This precipitate is more or less copious in samples of known purity but only slight in adulterated samples, since the substances used for adulteration do not contain malic acid.

In the so-called Hill and Mosher method special stress is laid on the malic acid value, not only as to quantity but also as to the manner in which it is precipitated and how it filters. The malic acid is precipitated by neutral lead acetate, filtered, de-

*Read by title.

composed by hydrogen sulphide, and the malic acid in the filtrate determined by titration with deci-normal alkali. This process has given excellent satisfaction, but has the following objections: In some maple products, especially the adulterated ones, it is exceedingly difficult to make a satisfactory filtration of the precipitated lead sulphide, sometimes requiring days before the filtrate has passed through the filter; the filtrate is most always too dark or turbid to admit of a satisfactory titration and observation of the end reaction; and then there is the always objectionable use of hydrogen sulphide.

These objections I have overcome by modifying the process as follows: the first precipitate with the lead acetate, after washing, is transferred together with the filter to a beaker, nitric and hydrochloric acid are added and the beaker heated on a hot plate; finally add sulphuric acid, evaporate to fumes; if blackening occurs, add a little nitric acid, and then again to fumes of sulphuric acid; allow to cool, dilute, add alcohol, let stand for several hours, filter and determine lead as usual. Calculate to lead per 100 c.c. of syrup or equivalent of sugar.

It is hoped to present in the near future in this journal a detailed account of this method, as well as analytical data obtained on various maple products.

University of Buffalo, June 28, 1906.

THE MASSACHUSETTS CIVIL SERVICE REFORM AUXILIARY offers free of expense, pamphlets on Civil Service Reform to Grammar Schools, High Schools, Normal Schools and Colleges willing to make these pamphlets the subject of a lesson in their Civics or American History Course. During the past five years over 125,000 of the pamphlets have been distributed to more than 1500 schools and colleges scattered throughout every State and Territory of the United States.

The titles of two of the pamphlets whose educational value has been so widely recognized by our teachers are "The Merit System, The Spoils System," by Edward Cary, and "The Merit System in Municipalities," by Clinton Rogers Woodruff. A third simpler pamphlet prepared by Miss Elizabeth Luther Cary for Grammar School use is called "A Primer of the Civil Service and the Merit System." As the circulation of this offer directly to the heads of schools and colleges must of necessity be gradual, the Massachusetts Auxiliary takes pleasure in announcing to teachers and others interested in the subject that copies of the above pamphlet, together with other of its publications, may be obtained free on application to the Assistant Secretary, Miss Marian C. Nichols, 55 Mount Vernon Street, Boston, Mass.

Section of Photography and Microscopy.

(Stated Meeting, held Thursday, April 19, 1906.)

On the Application of Farmer's Method of Reduction by Which the Shadows Are Preserved and Only the High Lights Reduced.

MR. JOHN BARTLETT, PHILAD'A.

The objection made, hitherto, to the so-called Farmer's solution for the reduction of too great intensity in the developed plate has been to the tendency of this agent to destroy the detail in the shadow parts of the negative, while acting upon the high lights, that is the thin portions suffered inordinately while the denser parts were reducing.

It was for this reason that the Lumière Bros. advocated the use of ammonium per-sulphate as a substitute on account of its more harmonious action on the film, that is attacking in preference the denser portions before acting on the shadows.

The ammonium per-sulphate undoubtedly does what is claimed for it, and in the majority of cases will be found to work effectively, but at times it is refractory, apparently not acting at all, even during a protracted manipulation, and on occasions acting injuriously upon the film by causing unevenness and stain or discoloration. Besides, its application requires considerable experience in manipulation to insure success, and also to preserve the plate from subsequent action which sometimes ruins the plate.

By a happy chance the writer was fortunate in discovering that the old stand-by, the ordinary so-called Farmer's solution, might be made under certain modifications to work as har-

moniously as the per-sulphate, that is to preserve the shadows while the high lights were reducing—with the further recommendation of its ease of manipulation and celerity of operation.

As everyone who works in photography knows, Farmer's solution is composed of a mixture of ferri-cyanide of potassium and hypo-sulphite of sodium. Saturated solution of ferri-cyanide potassium, 1 part, hypo-sulphite soda (1-5) 10 parts.

The novelty of my method is only in the constitution of the solution and the mode of its application. My attention was first called to the modification by observing how much more readily and harmoniously a plate reduces when the operation of reduction is performed immediately after the fixing of the plate and before any of the hypo in the film has been washed out. We are all liable, at times, to over-develop and to produce negatives which are harsh, dense and lacking in half-tones, and the fact is frequently patent to us on examination directly after removal from the fixing bath. And so it is the practice of many of us to reduce our obdurate plate then and there, before we place the plate in the washing tank. It was by noticing the better results so obtained that I was led to investigate the cause, and I found the reason to be that the unwashed plate had an excess of hypo in the film over the washed and dried plate reduced on the Farmer's solution made according to the old formula. That is, in order to get good results the hypo must greatly preponderate over the red prussiate of potassa or potassium ferri-cyanide. When the ferri-cyanide is in excess the shadows suffer the most. So the whole solution of the problem for harmonious reduction is to have an excess of hypo. Now, this might be told in a few words, and so I will briefly narrate my plan of manipulation, feeling assured that hereafter all who try the method will prefer the modified form of the Farmer's reducer to per-sulphate of ammonium.

On general principles it is best to reduce immediately after fixing, previous to washing, making the film acid with acetic or citric acid, and then placing it in a 5 per cent. solution of ferri-cyanide of potassium, lifting the plate up out of the reducer after a few minutes' immersion to note the effect, for the action must not be allowed to continue too long or the shadows will suffer.

When sufficiently reduced transfer immediately to the tap

and subject the plate to at least five minutes' washing; for although ferri-cyanide is a very soluble salt, it persists some time in the film, and if left to remain will go on acting and may thus carry the action too far.

When it is necessary to reduce a plate which has been thoroughly washed from hypo, the plan best to pursue is, first of all, to soak the film in a bath of weak acid, say 10 per cent. for five or ten minutes, and then to transfer it to a bath of hypo for another ten minutes, and finally to the action of a reducer composed of hypo and ferri-cyanide constituted as follows:

Saturated solution of hypo, 4 parts; saturated solution of ferri-cyanide, 1 part; made acid with citric or acetic acid sufficient to redden litmus paper.

This method of reduction also lends itself kindly to the manipulation of paper prints—bromide or solio—for entire or local reduction of too great intensity. The paper print must be thoroughly saturated with hypo, rinsed slightly off and then subjected to a diluted reducer constituted as above. That is, more water should be added, and for local reduction a tuft of cotton dipped in the solution may be employed upon the wet print.

ANNUAL REPORT OF RECLAMATION SERVICE.

The second edition of the Third Annual Report of the Reclamation Service, now published by the United States Geological Survey, is worthy of more special attention than was the first edition, because it is accompanied by a collection of fifty-nine maps, separately bound, which were prepared after the close of the field season as illustrations to the text. As the accompaniment is sometimes better than the song, so these maps may give to many a clearer idea of the reclamation work projected and now in progress than does the written record.

This report shows that examinations and surveys, as required by law, have been carried on throughout the arid regions, and that construction has been begun and has progressed rapidly wherever the surveys have demonstrated the practicability of a project. Taking into account the wide distribution of operations and the initiative and judgment which must be left to the engineers, it is believed that the results of the work are highly satisfactory.

This report is published for general distribution and may be obtained on request to the Director of Geological Survey. The usual quota is also supplied to members of Congress.

Annual Reports of the Schools of Drawing, Machine Design and Naval Architecture for the Sessions of 1905-1906.

THE DRAWING SCHOOL.—The attendance in the several classes has been larger than last year. This is particularly true of the Architectural and Free Hand Classes, which have been very successful, and have done remarkably good, practical work. The increase in the mechanical classes has been small. Of course the location of the building and the absence of imposing and attractive accommodations has much to do with this, and it is greatly to be regretted that we are so poorly housed, and are so deficient in the material attractions of the modern school. As regards the actual instruction we remain pre-eminent, and for a logical, practical, up-to-date course, there is nothing superior. Every instructor is daily at work at what he is teaching. There is very little pedagogism but plenty of engineering, architecture and design. What we need is legacies, for it is impossible to make an institution of this kind efficient and progressive, and at the same time self-supporting.

WM. H. THORNE,
Director.

THE FOLLOWING STUDENTS HAVE DESERVED HONORABLE MENTION:

In the Senior Mechanical Class.

Edward C. Pladder,	Clayton H. Robson,
Paul Saltzmann,	Elmer Cornell,
Frank H. Lobb,	William E. Press,
Frederick Fisher,	John H. Senior.

In the Intermediate Class.

Thomas P. Keeley,	William Underhoffer,
Joseph McFadden,	James T. Fennell.
Henry Schwemmer,	

In the Junior Class.

John A. Schaeffer,	Leonard Ware,
Howard G. Balz,	Alongo C. Love,
Horace Jackson,	Edward Jackway.

In the Architectural Class.

Charles Sticker,	Benjamin Batten,
William R. Rice,	William C. Klein, Jr.,
Harry Morse,	Daniel Henon.

In the Free Hand Class.

Joseph Hadik,	Joseph McCarthy,
Valentine J. Huegel,	Paul Baer.

James McDonald;
Joseph Kircher,
Edward Wilson, Jr.,
William Danks,

Joseph M. Lenoir,
George G. Gilson,
Francis A. Chiffelle,
James C. Norris.

THE SCHOOL OF MACHINE DESIGN.—We are pleased to report a substantial increase in the number of students attending our classes this year over those of last year. The interest of the students has been well sustained, especially in the classes in Strength of Materials and Machine Design, subjects which appeal to men more directly than mathematics, though no more essential to the engineer. The work done in the school of Machine Design should be of especial interest to draftsmen, and we find that the man who can make a neat and accurate drawing profits largely by our courses. Such being the case we see no reason why the men in the Drawing School should not graduate from there to our school; and we extend to the Drawing School graduating class of 1906 a cordial invitation to continue their good work by registering in our school next September.

We again express our gratitude to Professor Marburg for giving a series of lectures to our students on Stresses in Structures.

L. M. ARKLEY, *Director*.

The following students have successfully passed their examinations, their names being arranged in order of merit:

Machine Design.

	Ruch, F. J.,
Equal.	Fulmor, Wm. Jr.,
	Kircheubel, Edward,
	Bonderenko, E.

Mechanics.

Megonigal, Wm. S.,	Morison, R.,	
Smith, J. H.,	Aroson, S. G.,	} Equal.
St. Phalle, F. de,	Schmid, John,	
Kilmore, J. B.,	Ruch, H. J.,	
Rice, Wm. G.,	Groben, H.	

Strength of Materials.

St. Phalle, F. de,	Megonigal, W. S.,	
Kilmore, J. B.,	Aroson, S. G.,	} Equal.
Smith, J. H.,	Ruch, Herman,	
Phillips, C. E.,	Morison, R.,	

Schmid, John.

Trigonometry.

Register, F.,	} Equal.	Myers, E. L.,
Wackenhut, J. H.,		Hatfield, A.,

Hopping, E.

Geometry.

Hatfield, A.,	Hopping, E.,	} Equal.
Wackenhut, J. H.,	Myers, E. L.,	
	Register, F.,	

THE FOLLOWING STUDENTS ARE AWARDED SCHOLARSHIPS FROM THE B. H. BARTOL FUND:

Charles W. King,
Charles T. Huegle,

David Bowers,
William Markert.

THE FOLLOWING STUDENTS, HAVING ATTENDED A FULL COURSE OF FOUR TERMS, WITH SATISFACTORY RESULTS, ARE AWARDED CERTIFICATES:

E. LeRoy Hopping,
Edward C. Pladder,
John William Patterson,
Alfred L. Carson,
Robert A. Feroe,
Edwin F. Bramin,
Frank H. Lobb,
Paul Saltzman,
Joseph Mullen, Jr.,
Rudolph Bergersrode,
Benjamin Batten,
Paul Baer,

Thomas J. Delany,
Warren G. Harbison,
William E. Press,
Frank Butler,
Joseph M. Schneider,
John H. Senior,
George Chew,
Frank Dietz,
William R. Rice,
Harry Morse,
J. Robert Lauer,
Frank Kerner.

THE BRANCH DRAWING SCHOOL, located at Kenderton Hall, Seventeenth and Venango Streets, has had a successful year, both as to the number of students enrolled and progress in the study of Mechanical Drawing, which is the only branch taught in this school. The removal of the school to its present location, where it has had increased space and facilities, and the good work accomplished by the students, have been the source of much encouragement to the directors and instructors. Manufacturing concerns in the neighborhood of the school have manifested a warm interest in its welfare and have given aid by recommending their young men to attend the school, and also by financial assistance in its maintenance.

H. R. STACKS,
Director.

THE FOLLOWING STUDENTS HAVE DESERVED HONORABLE MENTION:

Harry Pannepacker,
Frank McKeon,
Vincent Casey,

Albert Grant,
Weston Mattis,
Edward Merriam,

H. M. Reynolds.

THE FOLLOWING, HAVING COMPLETED THE FULL COURSE OF FOUR TERMS, ARE AWARDED CERTIFICATES:

Albert Lehman,
William B. Neville,
George A. Peterson,
Harry W. Waltz, Jr.,
Charles Bottke,
Nelson Eastburn,
James Wakefield,
Kennard Vaughan,

Paul Kennedy,
Howard Blease,
Elmer Costello,
John P. Erdel,
Harry Plant,
George I. Bartleson,
Isaac Birch,
Albert Digiacomio,

Algebra.

Brittain, W. F.,
 Schmid, W. L.,
 Donahue, R.,
 Morrison, R. W.,
 Gickler, A. M.,
 Goetfel, E.,

} Equal.

Hasson, J. J.,
 Davis, W. A.,
 Frayne, L.,
 Petri, A. H.,
 Gauer, F.,
 Gardener, E. C.

} Equal.

THE SCHOOL OF NAVAL ARCHITECTURE.—The present depression in shipbuilding and the unstable condition of the industry, resulting in a decreased demand for men of technical training, has been responsible for a reduction in the number of students taking the naval architecture course. The uncertainty as to the future of shipbuilding in this country has had its effect in making young men somewhat reluctant about adopting naval architecture as a profession and has resulted in a marked diminution in the number of students preparing for this vocation, not only in Franklin Institute, but in nearly every technical school in the country.

The enrollment at the beginning of the school year, while below the average, was satisfactory, but adverse conditions which affected the students personally produced a considerable decrease in the attendance. Those who enrolled at the beginning of the Spring term have established a record for attendance that is remarkable. Scarcely an absence has been recorded against any of them and the majority have attended every session.

Considering that the students have been severely handicapped by a lack of the usual appliances of a drawing office, they have shown excellent progress. The presentation of abstract theories has been excluded as being considered of no practical value under the circumstances, but an attempt has been made to supply a large amount of information that would be of benefit in the drawing room or in making an elementary practice of the profession. It has been thought best to give most of the instruction by means of lectures supplemented by the use of text-books. This affords a better opportunity to consider those particular phases of the subject that appear important and essential and permits the special consideration of matters that are often omitted from text-books. An encouraging feature has been the earnestness of purpose and the evident desire to learn which all the members of the class have manifested.

The course is now well organized and arranged to suit the needs of the particular class of students which it is designed to serve, and it is hoped that a revival of shipbuilding will result in larger classes next year.

The following students have completed the full four-term course and are entitled to certificates:

Alfred A. Eichler,

James J. Holland.
 MELVILLE H. KEIL, *Director.*

Franklin Institute.

(Proceedings of the stated meeting held Wednesday, June 20, 1906.)

President JOHN BIRKINBINE in the chair.

Present, members and visitors. Additions to membership since last report, eleven.

The announcement was made of the presentation to the Institute, by Mrs. T. S. C. Sulley Darling, and Messrs. Burnham, Williams & Co., of a handsome portrait in oil, of the late Mathias W. Baldwin, founder of the Baldwin Locomotive Works, and active in the management of the Institute in its early days.

After some appropriate remarks by the President, Prof. Lewis M. Haupt, duly seconded, moved a vote of thanks to the donors, which was unanimously adopted.

Prof. Haupt then presented a communication on what he termed "Aneverending Problem," which related to the subject of the interoceanic canal across the American Isthmus. Discussed by Dr. Edward Goldsmith, Mr. L. E. Levy, the President and the speaker.

The meeting passed a vote of thanks to the speaker of the evening, and the session was adjourned.

LEWIS E. LEVY, *Sec'y pro tem.*

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AUGUST, 1906

The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

Mining and Metallurgical Section.

The Petroleums of North America. A Comparison of the Character of Those of the Older and Newer Fields.*

BY CLIFFORD RICHARDSON.

(Concluded from vol. clxii, page 70)

OHIO-INDIANA FIELD.

Before 1885 the main supply of petroleum on the continent of North America was derived from the Appalachian field, the oil bearing strata not being of greater antiquity from a geological point of view than the lower Devonian. In that year a new field was developed in the North-western part of Ohio, the oil occurring in Trenton limestone of lower Silurian age. This, although a paraffine petroleum, differs essentially from the paraffine petroleum of the Appalachian field in that it is denser, contains a larger amount of sulphur, including hydro-

*Read by title.

gen sulphide, which gives it a very bad odor, and yields a much smaller amount of distillate suitable for illuminating purposes.

According to Mabery* the density of the petroleum from the Findlay and Lima fields varies, in the former case from .8194 to .8296, 40.8°B., to 38.8°B, and in the latter from .8243 to .8510; 39.8° to 34.5°B. The ultimate composition of the oil shows a smaller percentage of carbon, 84.57%, as might be expected. The percentage of distillates which he obtained from the crude petroleum of Pennsylvania and North-western Ohio, with their densities, compare as follows:

Pennsylvania.			Ohio-Indiana.		
Fraction.	Parts in 100.	Sp Gr.	Fraction.	Parts in 100.	Sp. Gr.
120-150°	19.70		100-150°	9.75	.7282
150-200	8.84	.757	150-200	16.63	.7669
200-250	15.23	.788	220-257	10.75	.7940
250-320	20.70	.809	257-300	9.75	.8138
			300-350	8.63	.8242
Total	64.47			55.51	
Residue	35.52			43.50	

It will be noted that the distillates coming over below the boiling point of nonane, 151°, amount to twenty per cent. of the Pennsylvania and only ten per cent. in the Ohio oil, and that all the distillates from the latter are denser than those from the Pennsylvania oil.

Mabery† has made an elaborate study of this petroleum and has detected the paraffine hydrocarbons, C_nH_{2n+2} from butane, C_4H_{10} , boiling at 0°, up to and including a decane, $C_{10}H_{22}$, boiling at 173°, and corresponding to those found in the Pennsylvania petroleum. Above this the liquid members of this series fail. The solid paraffines occur, however, in a greater proportion than in the Pennsylvania oil, as they are present and separate out on cooling from all distillates above 150° at 30 mm. pressure. These solid paraffines have been assumed by Mabery, and probably correctly, to be identical with those found in the Pennsylvania oil. Above $C_{11}H_{24}$ satur-

*Am. Chem. Jour., 1895, 17, 725.

†Am. Chem. Jour., 1895, 17, 725.

Proc. Am. Acad. A. & Sci., 1904, 40, 323.

ated hydrocarbons are found which on separation from the solid paraffines by freezing, correspond to the general formula C_nH_{2n} , with 12, 13, 14, 15, 16 and 17 atoms of carbon, having the following boiling points, specific gravities, and index of refraction:

HYDROCARBONS SEPARATED FROM OHIO TRENTON LIMESTONE PETROLEUM.

Series.	Symbol.	Boiling Point.	Pressure.	Specific Gravity.	Refractive Index.
C_nH_{2n}	$C_{12}H_{24}$	211-213°	At. pressure.	.7970	1.4350
"	$C_{13}H_{26}$	223-225	"	.8055	1.4400
"	$C_{14}H_{28}$	138-140	30 mm.	.8129	1.4437
"	$C_{15}H_{30}$	152-154	"	.8204	1.4800
"	$C_{16}H_{32}$	164-168°	"	.8254	1.4514
"	$C_{17}H_{34}$	177-179	"	.8335	1.4545

When the carbon atoms reach 19 in number and up to and including hydrocarbons having 21, 22 and 24 atoms, the relation of carbon to hydrogen corresponds to the general formula C_nH_{2n-2} .

Series.	Symbol.	Boiling Point.	Pressure.	Specific Gravity.	Refractive Index
C_nH_{2n-2}	$C_{19}H_{38}$	199-202°	30 mm.	.8364	1.4614
"	$C_{21}H_{40}$	213-217	"	.8417	1.4650
"	$C_{22}H_{42}$	224-227	"	.8614	1.4690
"	$C_{24}H_{46}$	237-240	"	.8639	1.4715

The hydrocarbons with 23, 24 and 25 atoms of carbon correspond to the general formula C_nH_{2n-4} .

Series.	Symbol.	Boiling Point.	Pressure.	Specific Gravity.	Refractive Index
C_nH_{2n-4}	$C_{23}H_{42}$	253-255°	30 mm.	.8842	1.4797
"	$C_{24}H_{44}$	263-265	"	.8864	1.4802
"	$C_{25}H_{46}$	275-278	"	.8912	1.4810

It appears from the preceding data that the saturated C_nH_{2n} hydrocarbons of higher boiling point begin at a much lower number of carbon atoms than in the case of the Pennsylvania oil. The same can be said of the saturated hydrocarbons C_nH_{2n-2} , while hydrocarbons of the series C_nH_{2n-4} are present which are not found in the Eastern oil. They correspond physically and chemically with those found in the asphaltic petroleums from Texas and California and in the lighter distillates from the solid bitumens, such as Trinidad

asphalt, as may be seen from a comparison of the characteristics of the three latter materials, of about the same boiling point, with the C_nH_{2n-4} hydrocarbons of Ohio oil.

	Trinidad Asphalt Distillate.	California Distillate.	Beaumont, Texas, Distillate.
Boiling Point.....	300-310°	265-270°	293-317°
Specific gravity.....	.8914	.8860	.8879
Refractive Index.....	1.4815	1.4860	1.4830
Carbon	85.98 %	86.59 %	85.95 %
Hydrogen	13.62%	13.32 %	13.48%

Mabery* has also found a much larger percentage of aromatic hydrocarbons in Ohio oil and mentions the occurrence of benzol, toluol and mesitylene boiling at 168°, and the higher homologues, including cumol, psuedocumol, durol, isodurool, cymol, isocymol, and doubtless others of even higher molecular weight.

The naphthenes or monocyclic polymethylenes are also found in Ohio oil to a very considerable extent, but have not been separated in detail.

With these data alone it is evident that Pennsylvania and Ohio oils are of quite different character, aside from the presence of the larger amount of sulphur derivatives in the Ohio oil and of asphaltic hydrocarbons containing 23, 24 and 25 atoms of carbon.

The sulphur compounds have not been isolated but are probably of the same nature as those occurring in Canadian petroleum.

In the same way, as in the case of the Pennsylvania petroleum, the residue from the distillation of oil from the Ohio field has been examined by the writer with the following results:

PHYSICAL PROPERTIES.

Specific gravity, 25/25°.....	.9318
Flash	224°

CHEMICAL CHARACTERISTICS.

Loss, 160°, 7 hours.....	3 %
Character of residue.....	Soft.

*Proc. Am. Phil. Soc., 1897, 36, 154.

Loss, 200°, 7 hours (fresh sample).....	7.4 %
Character of residue.....	Soft.

Bitumen soluble in CS ₂ , air temperature.....	99.4 %
Organic matter insoluble.....	.6
Inorganic or mineral matter.....	.0
	100.0

Bitumen insoluble in 88°B. naphtha, air temperature—pitch.....	3.8 %
Per cent. of soluble bitumen removed by H ₂ SO ₄	17.0
Per cent. of total bitumen as saturated hydrocarbons.....	83.0

Per cent solid paraffines.....	11.4 %
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Fixed carbon.....	3.7 %
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From the preceding results it appears that there is no such striking difference between the two residues, as might be expected from the difference in the character of the oil in which they have originated. That from the Ohio oil contains about the same amount of unsaturated hydrocarbons removed by acid; and of paraffine scale, while it yields one per cent. more of fixed carbon. The density, as might be expected, is somewhat higher.

From the preceding data it is evident that the oil of the North-western Ohio field may be classed as a paraffine petroleum, but that it differs essentially from that of Pennsylvania in the nature of the liquid hydrocarbons of which it is made up, especially in the presence of asphalt hydrocarbons. It also contains larger amounts of naphthenes, or monocyclic polymethylenes, of aromatic hydrocarbons, of unsaturated hydrocarbons and of sulphur derivatives.

CANADIAN FIELD.

Petroleum occurs in the Province of Ontario, Dominion of Canada, in the corniferous limestone, of a character somewhat resembling that from the Ohio-Indiana field, as it contains sulphur, although in a rather larger amount, one per cent., as compared to six-tenths of one per cent. It has a very considerably higher density, .84 to .88, 36.7° to 29.1°B. It has been

closely studied by Mabery* who finds that in ultimate composition it compares with Ohio oil as follows:

	Canadian.	Ohio.
Carbon	.83.94 %	84.57 %
Hydrogen	13.37	13.62
Sulphur	.99	.60
	98.30	98.79

The comparative yield of distillate from the two oils is presented by Mabery as follows:

CANADA.		
	(Petrolia..)	
Boiling Point.	Per cent.	Specific Gravity.
100-150°	2.75	.7670
150-200	7.80	.8026
200-250	9.50	.8228
250-300	5.10	.8345
300-350	3.10	.9037
Total	28.25	
Residue	70.12	
OHIO.		
110-150°	9.75	.7282
150-220	16.63	.7669
220-257	10.75	.7940
257-300	9.75	.8138
300-350	8.63	.8242
Total	55.51	
Residue	43.00	
PENNSYLVANIA.		
120-150°	19.70	
150-200	8.85	.757
200-255	15.23	.788
255-320	20.70	.809
Total	64.48	
Residue	35.52	

*Am. Chem. Jour., 1896, 18, 53, and 1897, 19, 419.

Proc. Am. Phil. Soc., 1903, 42, 36.

Proc. Am. Acad. A. and Sci., 1904, 40, 334, and 1905, 41, 89.

From the preceding figures it is very evident that the Canadian petroleum contains a very much smaller percentage of hydrocarbons distilling at comparatively low temperatures, than either the Ohio or Pennsylvania oil.

In the Canadian, as in the Ohio oil, the liquid members of the series C_nH_{2n+2} stop with $C_{10}H_{22}$, but the proportion of these present is, of course, much smaller. Above this point the liquid hydrocarbons are poorer in hydrogen, and include the C_nH_{2n-2} and C_nH_{2n-4} series, of which the following were separated:

	Boiling Point.	Pressure.	Sp. Gr. 20°	Refractive Index.
$C_{12}H_{24}$	216°	760 mm.	.....	.....
$C_{13}H_{26}$	228-230	760 mm.	.7979	1.444
$C_{14}H_{28}$	141-153	50 mm.	.8096	1.449
$C_{15}H_{30}$	159-169	50 mm.	.8192	1.452

The aromatic hydrocarbons have been shown to be present in greater amount than in Pennsylvania or even Ohio oil. The sulphur compounds, owing to the larger percentage of sulphur present, are of much importance in affecting the character of the oil. Mabery* has isolated those containing from seven to eighteen atoms of carbon, corresponding to the general formula $C_nH_{2n}S$, having the following characteristics:

	Boiling Point.	Sp. Gr. 20°	Refractive Index.	Pressure.	Sulphur.
$C_7H_{14}S$	158-160°	.8878	1.468	760 mm	24.61 %
$C_8H_{16}S$	167-169	.8929	1.486	"	22.22
$C_9H_{18}S$	183-185	.8937	.....	"	22.22
$C_9H_{18}S$	193-195	.8997	1.4746	"	20.25
$C_{10}H_{20}S$	207-209	.9074	1.4766	"	18.60
$C_{11}H_{22}S$	128-130	.9147	1.480	50 mm	17.20
$C_{14}H_{28}S$	160-170	.9208	1.4892	"	14.04
$C_{16}H_{32}S$	170-180	.9222	1.4903	"	12.50
$C_{18}H_{36}S$	190-210	.9235		"	11.27

Mabery† has identified a number of the unsaturated hydrocarbons of the C_nH_{2n} series, obtained from sludge produced in the purification of the saturated hydrocarbons, as hexylene, heptylene and nonylene, the presence of which is of interest

*Proc. Am. Acad. A. and Sci., 1905, 41, 89.

† Proc. Am. Acad. A and Sci., 1905, 41, 107.

and which may possibly occur in smaller amounts in Pennsylvania and Ohio petroleum.

The naphthenes or monocyclic polymethylenes do not seem to have been isolated from Canadian oil, probably owing to the small percentage of light distillates which the petroleum contains.

The residues from these distillates have been found by the writer to be very rich in scale paraffine, as shown by the following results:

PHYSICAL PROPERTIES.

Specific Gravity, 25/25°	0.9355
Flash	233°

CHEMICAL CHARACTERISTICS.

Loss, 160°, 7 hours	.2 %
Character of residue	Soft.
Loss, 200°, 7 hours	7.8 %
Character of residue	Soft.
Bitumen soluble in 88°B naphtha, air temperature—Pitch	4.7 %
Per cent. of soluble bitumen removed by H ₂ SO ₄	10.0
Per cent. of solid paraffines	19.0 %

That such a large percentage of solid paraffine adds to the stability of this residue is seen by the fact that but 10% is removed on treating it with naphtha solution with strong sulphuric acid. The showing in this respect is in contrast to that of the residues from the Pennsylvania and Ohio oils, where the amount removed may reach 20%.

From the preceding data it appears that the Canadian oil, like that from Pennsylvania and North-western Ohio, may be classed as a paraffine petroleum, since it contains a predominating amount of hydrocarbons of the C_nH_{2n+2} series, especially in the solid form. It differs from these petroleums in that the amount of distillate below 150° is very much smaller, while the sulphur derivatives of the polymethylenes are present in very much larger amount, as are the aromatic and unsaturated hydrocarbons in the lower distillates, while the higher residues contain larger percentages of the solid paraffines and less unsaturated hydrocarbons. It resembles Ohio oil in having the lower liquid asphaltic hydrocarbons as components.

COLORADO FIELD.

Petroleum is found in several localities in Colorado, but the source of the principal industrial supply is in the Florence oil field. It is situated in Fremont County, in the valley of the Arkansas river, in close proximity to the eastern base of the Rocky Mountains.* The oil, a paraffine one, is contained in strata which are considered to belong to the Fort Pierce group of the Montana Cretaceous.† The crude petroleum is of a dark green color, of not unpleasant odor and has an average gravity of .8696, 31.0°B. It contains but a very small percentage of naphtha and yields from 35 to 40% of illuminating oils.

The hydrocarbons composing this distillate are largely of the C_nH_{2n+2} series, but the individual members have not been isolated nor is it known at what point hydrocarbons in which the percentage of hydrogen to carbon is smaller, begins.

The residuum is rich in paraffine. An examination by the writer resulted as follows:

PHYSICAL PROPERTIES.

Specific gravity, 25/25°.....	.9268
Flash	221°

CHEMICAL CHARACTERISTICS.

Loss, 200°, 7 hours.....	2.4 %
Character of residue.....	Soft.

Bitumen insoluble in 88° naphtha, air temperature—Pitch.....	.1 %
Per cent. of soluble bitumen removed by H_2SO_4	19.0

Per cent. of solid paraffines.....	10.4
------------------------------------	------

Fixed carbon	1.6 %
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It will be seen that this residuum is quite similar to that from the Eastern paraffine oils in all respects.

Petroleum is also found near Boulder, Boulder County,‡ which in its crude state has a very low gravity, .8116, 42.5°B., corresponding to that of Pennsylvania oil. This oil, however,

*Geo. H. Eldridge, Trans. Am. Inst. Min. Eng., 1891.

†U. S. Census, Mines and Quarries, 1902, 739.

‡Contributions to Economic Geology, U. S. Geol. Survey, 1902, 322.

has not yet reached a position of great industrial importance. Unlike the Florence oil it carries 17% of naphtha.

Wells have been drilled in thirteen other counties in the State, but no supply of importance has been developed.

WYOMING FIELD.

Petroleum occurs, rather widely distributed, over the State of Wyoming. Industrially, the amount produced is of small importance, being only 11,542 barrels in 1904, and coming from the Salt Creek oil field in Johnson and Natrona Counties, about fifty miles north of Casper, on the North Platte River.

The oils are rather heavy, having a density of .91, 23.9°B. It is found in the sands in the horizon below the Fox Hill group of the Cretaceous, although some may be found in the Tertiary and in strata as old as the Carboniferous.*

The petroleum of Wyoming has not been examined with any degree of thoroughness, but sufficiently to show that it leaves an asphaltic residual pitch on distillation, although paraffine scale has been observed in some distillates. It is a dark green oil of reddish-brown color by transmitted light.

According to the late Professor W. C. Knight, of the University of Wyoming, on distillation with superheated steam distillates were obtained having a specific gravity as high as .97, 14.3°B., and over, while little or none was obtained lighter than .860, 32.8°B.

In other parts of the State, oils have been examined by Knight, having the same density and character as that from the Salt Creek field, but containing noticeable percentages of sulphur, .10 to .30, while in the so-called Bonanza field an oil of .845 gravity, 35.7°B., occurs, carrying but .015% of sulphur and containing 10% of distillate below 150°.

A petroleum having a gravity of .916, 22.8°B., obtained in the vicinity of Newcastle, Weston County, separates, according to Knight, paraffine scale.

From other parts of the State petroleum having a density as high as .98, 12.9°B., is found, and it appears, therefore, that the character of the petroleum of Wyoming is most varied,

*W. C. Knight, Bulletin No. 1, The School of Mines, University of Wyoming, 1896, p. 16.

ranging from a comparatively light oil of density .81, 42.8° B., to the heavy asphaltic oils of density .98, 12.9° B.

CALIFORNIA FIELD.

Petroleum is found in California principally to the south of the latitude of San Francisco, although prospects occur to the north of this which are at present of smaller industrial importance. The fields lie on either side of the Coast Range, those originally developed being along the sea coast in Santa Barbara, Ventura, Los Angeles and Orange Counties, while the largest fields are in the Central Valley of the State, to the east of the range in Fresno and Kern Counties, these two producing by far the largest amount of any in the State, although the latter has been developed only within the last six or seven years. Oil is also produced on a smaller scale in San Mateo and Santa Clara Counties.*

The oil-bearing strata are of from Eocene to Pliocene age, which are reached in wells at depths of from 300 to 3,000 feet.

The production of petroleum in California is the largest in amount of that in any State of the Union, although as a field that of the Appalachian is greater. It has increased sevenfold since 1900. Owing to its inferior character for the production of illuminating oil, the output is only fifth in value.

The density of California petroleum varies from .8235, 40.0° B., for some from Colusa County, .8485, 35.0° B., for that found in Santa Clara County, and from Fresno County, to .9859, 12.0° B. in Santa Barbara County. In color the oil varies from yellow to almost black.

As can be seen from its varying density, California petroleum is quite varied in character. The densest oil is found in the Summerland field in Santa Barbara County, in Los Angeles County, and in the Sunset field in Kern County. The characteristics of the oils can conveniently be taken up by counties or fields.

Santa Barbara County—Summerland Field: A specimen of

*For further information as to the occurrence of petroleum in California, see the *Petroleum Fields of California*, Eldridge, Contributions to Economic Geology, 1902, U. S. Geol. Survey, Washington, Government Printing Office, 1903.

the dense Summerland oil collected by the writer and distilled in vacuo at a pressure of 26 mm., gave 55% of distillate which was collected in fifteen fractions, having the following specific gravity at 20°.

Fraction.	Sp. Gr.
1	.8712
2	.8833
3	.8893
4	.9034
5	.9155
6	.9336
7	.9417
8	.9477
9	.9618
10	.9678
11	.9738
12	.9802
13	.9830
14	.9900
15	.9939 Ref. Index 1.542
Residue, 45 per cent. A hard asphalt.	
	Penetration 66.

The highest boiling fraction has a density very nearly that of water and a refractive index of 1.542. The residue consisted of a hard residual pitch. On redistilling the first fraction at the same pressure, distillates began to come over at 105°, having a specific gravity of .8460, 35.5°B., and a refractive index of 1.460. Paraffine scale could not be separated from any of the fractions on exposing them to an extremely low temperature.

Mabery* has examined this oil in considerable retail. He found that a sample which he obtained, having a specific gravity of .9845, 12.2°B., had the following ultimate composition:

Carbon.....	86.32 %
Hydrogen.....	11.70
Nitrogen.....	1.25
Sulphur.....	.84

100.11

His distillates were of a character similar to those found by the writer. He continued his fractionation until heaps were

*Proc. Am. Acad. A. and Sci., 1904, 40, 340.

obtained at certain temperatures. After purification with sulphuric acid and caustic soda, he examined the saturated hydrocarbons thus obtained with the following results:

HYDROCARBONS SEPARATED FROM SANTA BARBARA (CAL.) PETROLEUM.

Symbol.	Boiling Point.		Sp. Cr. at 20°	Ref. Index.
C ₁₃ H ₂₄	150-155°	60 mm.	.8621	1.4687
C ₁₆ H ₃₀	175-180	"	.8808	1.4700
C ₁₇ H ₃₀	190-195	"	.8919	1.4778
C ₁₈ H ₃₂	210-215	"	.8996	1.4814
C ₂₄ H ₄₄	250-255	"	.9299	
C ₂₇ H ₄₆	310-315	"	.9451	1.5146
C ₂₉ H ₅₀	340-345	"	.9778	

The most volatile of these fractions belong to the C_nH_{2n-2} series. With the third the series becomes C_nH_{2n-4}, and with the sixth C_nH_{2n-8}, the density of the last fraction and its boiling point being extremely high. A hydrocarbon of the C_nH_{2n-2} series of very similar molecular weight, has also been separated by the writer from Trinidad asphalt and found to have the following physical characteristics:

Boiling Point.....	147-170° at 30 mm.
Specific gravity.....	.8576
Beaumé.....	33.20
Refractive Index.....	1.465
Carbon.....	86.85%
Hydrogen.....	13.34

The resemblance between the physical properties and ultimate composition of these fractions with some of those obtained by Mabery, renders it probable that the same series are present in Trinidad asphalt as in California oil. The latter oil is, without doubt, extremely asphaltic in nature, as is evident from the fact that it leaves 45% of hard pitch, resembling asphalt, on distillation in vacuo.

On distillation with steam of the sludge obtained from treating the above distillates with strong sulphuric acid, the sulphur derivatives of the petroleum, the presence of which is shown by the ultimate analysis, have been recovered by the writer and found to correspond to those obtained in Canadian oil.

On treatment of the distillates with dilute sulphuric acid, one to four, the nitrogen derivatives, the presence of which is also

shown by the ultimate analysis, can be recovered. They are probably hydroquinolenes. Their examination has been undertaken by Mabery.* He finds that fractions of the nitrogenous oil, separated by repeated distillation, have the following composition:

130-340°	C ₁₂ H ₁₇ N
197-199	C ₁₃ H ₁₈ N
215-217	C ₁₄ H ₁₉ N
223-225	C ₁₅ H ₁₉ N
243-245	C ₁₆ H ₁₉ N
270-275	C ₁₇ H ₂₁ N

Santa Barbara County—La Graciosa District: In the interior of Santa Barbara County, near Santa Maria, in the Graciosa Hills, petroleum has been produced in large amounts very recently from wells which were opened up towards the close of the year 1903, on the Careaga Ranch. This oil† has a specific gravity of about .85, 34.7°B., and yields about 36% of distillate below 200°. It is much lighter than that from the Summerland field, and consequently of much greater value. It has not yet been examined in any detail.

Los Angeles and Orange Counties: The oil produced in Los Angeles County is of two kinds. That in the district including and immediately adjoining the city of Los Angeles being a heavy oil, of an average density, .9790, 13.0°B., with extremes of .9859 and .9396, 12.0 and 19.0°B., and largely associated with water. In two other districts, one adjoining the oil fields of Orange County and the other those of Ventura County, lighter petroleums are found. The former produced petroleum having a density of .9655, 15.0°B., to .9211, 22.0°B., while the latter, in Pico Canyon, furnishes one of the lightest oils found in the State, having a density of about .84, 36.7°B., yielding, according to Cooper‡ the following distillates:

Under 100°	10.5 %
100-150	20.4
150-200	13.8
200-250	13.0

*J. Soc. Chem. Ind., 1900, 19, 505.

†H. N. Cooper, Chemist of the California State Mining Bureau, Bulletin 31.

‡loc. cit.

250-300	11.1
Residue	31.2
	100.0

Solid hydrocarbons are separated from some of the distillates of this oil on cooling, and it has been stated that these are paraffines and that at one time they were extracted on an industrial scale. These solid hydrocarbons have not yet, however, been identified as paraffines by any acceptable authority. Solid hydrocarbons which are not paraffines have been separated from some of the oils from Ventura County, as will appear later,

A distillation of the petroleum from the Eastern Los Angeles County field, which was carried out by the writer, resulted as follows:

Fraction	Per cent.	Sp. Gr.	Refractive	Color.
26 mm.	Distillation.	20/20°	Index.	
136-178°	3.7	.8654	1.474	Light red.
178-198	3.8	.8760	1.480	Deeper.
198-205	3.8	.8865	1.486	"
205-232	3.7	.8986	1.495	"
232-235	3.8	.9101	1.502	"
235-240	3.8	.9196	1.509	"
240-254	4.0	.9314	1.517	"
254-265	4.1	.9420	1.523	"
265-289	4.0	.9502	1.530	"
289-293	4.0	.9743	1.533	"
293-298	4.8	.9796	1.536	"
Residue	59.0			Reddish - black, very viscous but flows slowly.

LOSS BY TREATMENT WITH DIFFERENT REAGENTS.

Fraction.	Sodium Hydrate NaOH	2-1 Sulph. Acid H ₂ SO ₄	Conc. Sulph- uric Acid.
130-178°	1.6 %	1.2 %	3.3 %
178-198	.8	2.1	6.3
198-205	1.5	2.3	6.8

The oil resembles that from the Summerland field and leaves on distillation a large percentage of asphaltic residue. Treatment of the lower distillates with sodium hydrate and acid removes but a comparatively small per cent. of nitrogenous

bases, sulphur derivatives and unsaturated hydrocarbons. When two hundred c.c. is distilled from an Engler distilling flask, the following percentages of distillate are obtained:

Under 200°	0.0 %
200-250	4.0
250-300	13.9

Cracking begins at temperatures much above 300°, and strong smelling distillates, amounting to 50%, may be obtained, leaving a residue of 30 to 40% of pitch, according to the care with which and the extent to which the distillation has been carried out. That a much larger percentage of pitch than this is obtained, was found to be the case by the writer, if the oil is allowed to evaporate in an open dish at from 12 to 24 hours, at a temperature of 200°, when as much as 60% will be obtained. In the actual distillation of such oils in the refineries the temperatures are often carried to 400°, or even higher, both distillates and residual pitch being much decomposed. The residual oils and pitches obtained in this way, when the greatest care is exercised in distillation, have the following composition:

CALIFORNIA RESIDUAL OIL.

("G" Grade.)

PHYSICAL PROPERTIES.

Specific gravity, 25/25°.....	1.006
Flashes	191°

CHEMICAL CHARACTERISTICS.

Loss 160°, 7 hours.....	3.2 %
Character of residue.....	Soft.

Loss 200°, 7 hours (fresh sample).....	17.3 %
Character of residue.....	Soft.

Bitumen soluble in CS ₂ , air temperature.....	99.7 %
Organic matter insoluble.....	.3
Inorganic or mineral matter.....	.0

100.0

Bitumen insoluble in 88°B. naphtha, air temperature—Pitch.....	7.7 %
Per cent. of soluble bitumen removed by H ₂ SO ₄	54.9
Per cent. of total bitumen as saturated hydrocarbons.....	41.9

Per cent. of solid paraffines.....	0.0 %
Fixed carbon	6.0 %

CALIFORNIA RESIDUAL PITCH.

("D" Grade.)

PHYSICAL PROPERTIES.

Specific gravity, 25/25°.....	1.062
Color of powder or streak.....	Black
Lustre	Lustrous
Structure	Uniform
Fracture	Tacky
Hardness, original substance.....	Sticky
Odor	Asphaltic
Softens	.61°
Flows	.69°
Penetration at 25°.....	.52

CHEMICAL CHARACTERISTICS.

Loss 160° 7 hours.....	.83 %
Character of residue.....	Hard.
Loss 200°, 7 hours (fresh sample).....	6.2 %
Character of residue.....	Hard.
Bitumen soluble in CS ₂ , air temperature.....	99.3 %
Organic matter insoluble.....	.4
Inorganic or mineral matter.....	.3

100.0

MALTHENES:

Bitumen soluble in 88° B. naphtha, air temperature.....	77.0 %
This is per cent. of total bitumen.....	77.5
Per cent. of soluble bitumen removed by H ₂ SO ₄	47.8
Per cent. of total bitumen as saturated hydrocarbons.....	40.5
Bitumen soluble in 62° B. naphtha.....	82.2 %
This is per cent. of total bitumen.....	80.0

CARBENES:

Per cent. of bitumen insoluble in carbon tetrachloride, air temp... .	.5 %
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Fixed carbon	15.0 %
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Residues like the above are known as California flux and California asphalt, and have been used more or less satisfactorily in the construction of asphalt pavement. They are free from paraffine scale and are distinguished from similar residues

from paraffine petroleum by yielding a much higher percentage of fixed carbon, the amount being proportionate to the hardness of the material.

Los Angeles County: Petroleum from the Southern part of Los Angeles County, in the Puente Hills, and the adjoining fields in Orange County is quite variable in character. Some of it has a density as high as .8537, 34.0°B., in the Olinda fields, while other oil from the same field has a density of .9396, 19.0°B. The lighter oil affords the following percentages of distillates, according to Cooper:

Under 100°	12.9 %
100-150	15.3
150-200	11.5
200-250	11.1
250-300	9.6
Residue	39.6
	—
	100.0

One of the denser oils has been examined by the writer with the following results:*

OIL FROM THE FULLERTON OIL WELLS OF THE A., T. & S. F. R. R.

Color	Brown
Specific gravity, 20/20°	.9393
Beaumé	19.5°
Loss 200°, 7 hours	42.7
Character of residue	Soft, maltha, sticky, and drawing to a long thread.
Flash	26°

Boiling Point.	Color of Distillate	Per cent. Distillated.	Sp. Gr. 25/25°	Refractive Index.
Atmos. Pressure:				
35-135°	Colorless.	2.4	.7880	1.423
135-175°	Pink.	8.2	.8319	1.435
25 mm. Pressure:				
40-100°	Green.	4.2	.8745	1.455
100-150°	Dark red.	10.4	.9195	1.478
150-165°	Dark red.	7.0	.9547	1.496
Begins to crack,				
Residue	.....	66.4	.....	.....
Loss, gas.	.....	1.4	.....	.....
		—		
		100.0		

*J. Soc. Chem. Ind., 1900, 19, 123.

The preceding distillates when treated with sodium hydrate solution and sulphuric acid lost the following percentages of phenols and bases:

	Per Cent. Distillate.	Loss with ten Per cent. soda.	Loss with con- centrated acid.
Boiling Point.			
Atmos. Pressure:			
35-135°	2.4	0.0	0.7
135-175	8.2	1.2	1.3
25 mm. Pressure:			
40-100°	4.2	2.3	4.7
100-150	10.4	2.9	4.9
150-165	7.0	6.8	13.3
Residue	66.4	8.7	33.3

Density of Distillates before and after Treatment.

Boiling Point.	Density		Refractive Index.	
	Before.	After.	Before.	After.
Atmos. Pressure:				
35-135°	.7880	.7338	1.423	1.430
135-150	.8319	.7798	1.435	1.437
25 mm. Pressure:				
40-100°	.8745	.8169	1.455	1.454
100-150	.9195	.8593	1.478	1.477
150-165	.9547	.8774	1.496	1.494
Residue	.....	.8975	.....	.....

Both of these substances can be recovered, the phenols at times in crystalline condition. The bases are the same as those found in other California oils, while they are accompanied by some aromatic hydrocarbons and sulphur derivatives, the oil carrying .28% of sulphur.

Ventura County: Ventura County is the location from which the earliest supplies of California petroleum were obtained as long ago as the sixties. The fields are scattered through its Southern part, on both sides of the Santa Clara Valley and in the neighborhood of Santa Paula.* The oils are of the most varied character, ranging from a very dense one carrying a large percentage of nitrogen and sulphur, in the Ojai district, to the lighter oil of the Bardsdale and Torrey fields, from the distillates of which solid hydrocarbons separate at ordinary temperatures. These oils have been examined by the writer with the following results:

*Mineral Resources, U. S. Geol. Survey, Eldridge, 1902.

OIL FROM OJAI VALLEY.

Fraction.	% Dis-tilled.	Loss with		Specific Gravity		Refractive Index	
		NaOH	H ₂ SO ₄	Before treatment.	After treatment.	Before treatment.	After treatment.
Original oil:				.9175			
30-80°	7.8	2.1	3.3	.7680	.7826	1.435	1.437
80-118	7.8	3.3	4.4	.7728	.8200	1.455	1.455
118-150	7.8	4.0	8.5	.8334	.8583	1.478	1.476
150-181	8.0	11.1	9.0	.8750	.8907	1.498	1.495
181-213	8.0	12.7	10.5	.8939	.9079	1.512	1.506
213-248	8.0	13.9	12.7	.9292	.9257	1.526	1.516
248-274	7.8	2.1	16.3	.9605	.9394	1.537	1.517
Residue.	43.8	....	....	1.0100	.....	.....	.....
Loss	1.0	....	....	.....	.....	.....	.....

This oil is marked by the fact that 11, 12 and 14% of the distillates boiling between 150 and 250°, at 26mm., consist of phenoloid bodies removed by treatment with sodium hydrate, while an almost equal amount of nitrogenous bases are removed by sulphuric acid. The change in the specific gravity of the distillates after treatment is striking, the result being an increase in some and decrease in others.

BARSDALE OIL.
Before Treatment.

Fraction	% Dis-tilled	Color	Sp. Gr. 20°	Refractive Index
Original		Deep brown-black	.8869 (29°B.)	
60-120°	10.0	Colorless	.7316	1.414
120-154	12.0	"	.7481	1.419
26 mm. Pres:				
48-116°	13.0	Light yellow	.7972	1.443
116-152	12.0	Light green	.8420	1.469
152-198	11.0	Darker green	.8724	1.486
198-255*	10.0	Yellow brown	.9035 (at 25°)	1.501
255-310**	6.0	Reddish brown	.9216 (at 45°)	1.521
Residue	25.4	Penetration about 60		

* Little paraffine.

** Solid with paraffine.

After Treatment.

Fraction	Color	Loss with		Sp.Gr.	Refractive Index
		NaOH	H ₂ SO ₄		
62-120°	Colorless	1.1%	1.7%	.7337	1.420
120-154	"	1.4	3.8	.7493	1.420
26 mm. Pres:					
48-116°	"	1.0	5.3	.7932	1.441
116-152	"	.9	9.0	.8330	1.463

152-198	Light Yellow	1.9	16.3 (a)	.8572	1.478
198-255	" "	1.6	18.7 (b)	.8900	1.498
255-310	Reddish Brown	1.3	34.7	9.001	1.510
(a) Melts at 25°.		(b) Melts at 43°.			

The preceding distillates, obtained at a pressure of 26mm., with the exception of the two lower fractions, have a very much lower density than those of the denser California petroleums. The distillates at atmospheric pressure below 150° amount to 22%. The fractions above 200°, at 26mm., all separate solid hydrocarbons which have not been closely identified. Mabery has examined a similar oil from the adjoining Torrey Canyon field and isolated from the distillates solid hydrocarbons in crystals that melt at 57° to 62°, and which are not paraffines. He also found* that this carried quite an amount of sulphur, .84%, and a very considerable percentage of nitrogen. The crude oil has the following composition:

Carbon.....	.85.60%
Hydrogen.....	12.84

In the lower distillates benzol and toluol were present in marked amount and the density of these distillates was much higher than would make it possible for the occurrence of C_nH_{3n+2} hydrocarbons, and it seems, therefore, from Mabery's examination that none of these exist and that the lower boiling components of this oil are aromatic and naphthene hydrocarbons.

The writer has also examined a specimen of the Torrey Canyon oil with the following results:

TORREY CANYON OIL.
Before Treatment.

Fraction	% Dis- tilled	Color	Sp.Gr. 20°	Refractive Index
Original oil		Dark reddish-brown	.8650	
Atmos. Pres :				
47-116°	6.0	Colorless	.7200	1.412
116-145°	12.4	"	.7523	1.428
26 mm. Pres :				
36-94°	12.7	Very light yellow	.7912	1.440
94-132	14.0	" "	.8255	1.458
132-195 (a)	17.6	Yellow	.8520	1.475

*Am. Chem. Jour, 1897, 19, 797.

195-242 (b)	15.0	Greenish	.8808	1.491
242-280 (c)	15.0	Dark yellow	.8981(40°)	1.504
280-310 (d)	6.2	Dark brown-reddish	.9156	1.523
	98.9			
Loss	1.1			

Residue, 24.6 %, is a hard asphalt with appearance of paraffine.

(a) Some solid hydrocarbons. (b) Considerable solid hydrocarbons.

(c) Solid hydrocarbons. (d) Solid hydrocarbons.

After Treatment.

Fractions	Color	Loss with			Ref. Index	Melts at
		NaOH	H ₂ SO ₄	Sp Gr.		
47-116°	Colorless	—	2.5%	.7232	1.418	—
116-145	"	—	2.8	.7542	1.424	—
26 mm. Pres :						
36-94°	"	—	5.1	.7903	1.441	—
94-132	"	0.5%	7.0	.8236	1.459	—
132-195	Light yellow	1.9	13.0	.8423	1.471	—
195-242	" "	2.2	15.2	.8528	1.482	—
242-280	Yellow	1.1	21.7	.8733	1.497	30°
280-310	"	1.4	24.2	.8878	1.504	36°

The gravity of the higher distillates in both the Bardsdale and Torrey Canyon oils is much less than in the usual asphaltic oils, and this, as has been said, is a very distinguishing character of these petroleums. For example, the distillates of the same boiling point in the Los Angeles, Torrey Canyon and Bardsdale oil compare as follows:

	Los Angeles.	Bardsdale.	Torrey Canyon.
Boiling point 30 mm.	293-296°	255-310°	280-310°
Specific gravity.....	.9796	.9216	.3878
Refractive Index.....	1.536	1.521	1.504

The Torrey Canyon oil carries a very considerably larger amount of solid hydrocarbons than the Bardsdale and the distillates are of much lower density and refractive index for the same boiling point. From a scientific point of view it is one of the most interesting petroleums of California and will eventually repay further and careful study.

The Torrey Canyon and Bardsdale oils differ most strikingly from that from the Ojai Valley by their lesser density, the presence of solid hydrocarbons and the absence of any considerable amounts of phenoloid bodies removed by sodium hydrate.

The petroleum from other fields in Ventura County are var-

ied in character but possess no such extreme characteristics as those which have been described, resembling much more the oils from other parts of the State. Typical of these oils is the following from the Sespe district:

FOUR FORKS OIL.

Before Treatment.

Fractions	% Distillate	Color	Sp.Gr. 20°	Refractive Index
Original oil		Reddish brown	.8651 (32.5°B)	
48-115°	Equal vol.	Colorless	.7483	1.418
115-148	" "	"	.7066	1.412
26 mm. Pres :				
56-96°	" "	"	.7855	1.437
96-138	" "	Light green	.8200	1.454
138-173	" "	" "	.8470	1.469
173-219	" "	" "	.8730	1.484
219-265	" "	Bright yellow	.9026	1.502
265-284	" "	Reddish brown	.9214	1.513
Residue	21.2	Penetration 340	—	—

After Treatment.

Fractions	Color	Loss with NaOH	H ₂ SO ₄	Sp.Gr.	Refractive Index
48-115°	Colorless	1.4%	.9%	.7512	1.424
115-148	"	1.5	1.1	.7102	1.412
26 mm. Pres :					
56-96°	"	.9	1.4	.7855	1.437
96-138	"	2.0	1.4	.8195	1.456
138-173	Light green yellow	3.1	4.6	.8435	1.469
173-219	" " "	4.6	6.8	Lost	—
219-265	Dark brown	4.6	5.3	.9151	1.499
265-284	" "	2.2	18.1	.9221	1.502

This is a light oil containing considerable distillate below 150° at ordinary atmospheric pressure. Above this point the distillation was carried on in a vacuum at 26 mm. and a residue of only 21%, having a consistency of thick flux, was left. None of the fractions showed any signs of solid hydrocarbons on freezing and they were not strongly acted upon by sodium hydrate or sulphuric acid. The second distillate under atmospheric pressure is remarkable for its specific gravity, this being very much lower than the lighter distillate which came off before it.

Like the Bardsdale and Torrey Canyon oil the specific gravity

of the heaviest distillate is much less desirable at the same temperature than that from Summerland, Los Angeles and other heavier oils, that is to say, it is not so asphaltic in its nature. These facts do not seem to have been brought out hitherto.

Central Valley of California: The most important oil fields of California are situated in the Central Valley to the east of the Coast Range, in the Counties of Kern and Fresno, which produced in 1904 respectively 19,608,045 and 5,114,958, or 24,723,003 barrels out of a total production in the State of 29,649,434 barrels.

Kern County: As a producer to any considerable extent Kern County first appears in 1900 with something less than a million barrels of oil, derived chiefly from the field on the Kern river, in the neighborhood of Bakersfield, although small amounts were produced in the Sunset and McKittrick fields.

The Kern river oil has a density of from .9859 to .9396, 12.0 to 19.0°B. It contains from .75 to 1.0% of sulphur and yields, according to Cooper,* the following percentages of distillates:

	19°B.		12°B.	
	Distillates.	Sp. Gr.	Distillates.	Sp. Gr.
Up to 100°	0.0	....	....	....
100-150	4.0	.779	....	....
150-200	8.4	.816	0.0	....
200-250	12.1	.864	2.4	.876
250-300	14.6	.898	25.0†	.899

†Cracking begins in this distillation.

This oil has not been examined as yet in greater detail.

An oil from a shallow well in the Sunset district, which lies on the western side of the valley, collected by the writer in 1898, had a density of .9784, 13.1°B. It was distilled in vacuo, 26mm., with the following results:

HEAVY OIL SUNSET DISTRICT^a—1897.

Distilled at pressure of 25 mm. after drying.

Fraction.	+ Dis- tillate.	Specific Gravity.	Refractive Index.
60-100°	.9		
100-145	8.0	.8670	
145-190	8.0		

*loc. cit.

190-220	8.0	.9209	
220-244	8.0	.9347	1.523
245-270	8.0	.9621	1.526
Residue	59.1	(Penetration 95)	

Fraction.	Treated with a 10% solution NaOH and H ₂ SO ₄ .			Refractive Index.
	Loss with NaOH	H ₂ SO ₄	Conc. H ₂ SO ₄	
60-100°	8.5 %			
100-150	4.7	1.5 %	3.5 %	.8656
145-190	5.1	.5	6.0	.8888
190-220	5.8	1.8	14.6	
220-244			26.4	.9408
				1.524

The higher distillates were so viscous that they flowed but slowly at ordinary temperatures and the most so of any distillates observed by the writer from California petroleum. No solid hydrocarbons separated from these distillates in a freezing mixture.

The second and third distillates were redistilled in a vacuum of 26 mm. after treatment with alkali and acid and the distillates collected in fractions of 5°. They were all water white.

Fraction.	Amount Distilled.	Specific Gravity 20°	Refractive Index
100°	20 c.c.	.8281	1.453
125-130	40	.8607	1.471
140-145	100	.8778	1.482
155-160	75	.8943	1.493
175-180	75	.9083	1.502
200-205	75	.9276	1.515
220-225	75	.9356	1.520
240-245	60	.9457	1.525
260-265	30	.9532	1.529
275-280	20	.9560	1.529
290-295	15	.9579	1.533

The above results can be compared with some interest with the distillates from Summerland oil, and it would appear that the hydrocarbons in the two oils are practically identical, but do not agree in all respects with those isolated by Mabery.

Fresno County: The petroleums of Fresno County are very varied in character and have a density of from .9859 to .8000, 12.0 to 45.0°B., but averaging .8589, 33.0°B. Cooper has

found from .06 to .94% of sulphur in the oil, while Mabery* from his examination of oil found in this county, having a density of .8423, 36.2° B., at 20°, found but .21% of sulphur, together with carbon 86.24 and hydrogen 13.08%. On distillation under atmospheric pressure he obtained the following fractions, all of which were colorless below 250°.

	Distillates.	Sp. Gr.
150°	33.06 %	.7829
150-200	24.79	.8268
200-250	20.66	.8725
250-300	12.40	.9090
Residue	9.09	.9356

These light petroleums have not been very carefully studied, but it is evident that they differ essentially, as shown by the specific gravity of the distillates, from the heavier California oils, and probably contain very considerable percentages of the naphthenes. No separation of paraffine scale or solid hydrocarbons from the distillates has been noted, but the lightest Fresno oils contain a certain percentage of asphalt, amounting to at least 5 to 10%.

From the preceding data it appears that the petroleums of California are of the most varied character and that all of them consist of more or less dense asphaltic hydrocarbons. Nitrogenous bases are often present in very large amounts and again in only small amounts. Phenols are a common constituent of the denser oils. Except in those constituents which boil at a comparatively low temperature the components of California oils are unique in their density and viscosity.

None of the components is of the paraffine series and the hydrocarbons being largely of the C_nH_{2n} and C_nH_{2n-2} series, among those of sufficient volatility to be used as illuminating oils the distillates below 150° do not make good burning oil. They burn with a smoky flame and must be mixed with a large proportion of Eastern kerosene before they can be used.

TEXAS FIELD,

The petroleums of Texas are somewhat varied in character and widely distributed over the State. They occur in strata of

*Am. Chem. Jour., 1897, 19, 803.

Cretaceous age in Corsicana, Bexar and Medina Counties, both heavy and light oils being found. In Corsicana, the first oil field of any scale opened in the State; and in Bexar, rather heavy oils occur, while in Medina County oil carrying as much as 32% of illuminants has been produced.* The largest additional supplies of petroleum are found in strata of Tertiary age in the Neocene in Jefferson County, on the Gulf Coastal Plain,† where the Beaumont developments were made in 1891, although the exact age of the latter has not been definitely determined, and in the Sour Lake district in Hardin County. The production of petroleum in Texas was not one of industrial importance before 1898, when over half a million barrels were obtained from the Corsicana field. In 1901 the well-known Beaumont or Spindle Top pool was discovered, and over three and one-half million barrels of petroleum of quite a different character from that of the Corsicana field was the record for that field for that year, becoming nearly seventeen and one-half million barrels in 1902, after which there has been a very rapid drop until the production of 1904 only equaled that of 1901. The Sour Lake field, in connection with the Saratoga field produced in 1903 nearly nine million barrels and the Batson Prairie field nearly eleven million barrels in 1904, although less than five million barrels in 1903. In 1904 a pool was opened in a locality, furthest to the South-west of the State, eighty miles from Houston, in Matagorda County, which produced 151,936 barrels of dark-green petroleum of .9393 to .9333, 19.0° to 20.0°B.‡ In Harris County a new pool, known as the Humble field, was also opened in that year, which possesses some interest. . Other pools producing oil of from .8140 to .9032, 40.2° to 25.0°B., are in existence and may be identified as follows:

Bexar County District: Only a small quantity of heavy petroleum was produced in 1902. It came from wells six hundred to eight hundred feet in depth, near San Antonio, and supplied a small local demand. This is not of industrial importance.

*The University of Texas Mineral Survey,, Bulletin No. 1, July, 1900, p. 36.

†Contributions to Economic Geology, U. S. Geol. Survey, C. W. Hayes, 1902, p. 345.

‡Mineral Resources, U. S. Geol. Survey, 1904. p. 713.

Nacogdoches County: Numerous shallow wells were drilled prior to 1895 near Oil Springs, in Nacogdoches County, some twelve miles South-west of the town of Nacogdoches. There has been a considerable outlay in drilling wells, establishing receiving tanks, and building a pipe line, all of which has been practically abandoned. Only a very limited quantity, supplying a local demand, is now marketed.

Brazoria County: At Kaiser Hill, near Columbia, Brazoria County, petroleum of good lubricating qualities has been developed, which, owing to a lack of transportation facilities, was not operated during 1904.

South Basque District: At South Basque, McLennan County, seventy miles South-west of Corsicana, oil is produced of .8140 to .9032, 42.0° to 25.0° B.

Henrietta District: At Henrietta, Clay County, one hundred and fifty miles North-west of Corsicana, 65,455 barrels were produced in 1904, having a gravity of .8589, 33.0° B. This oil is said to have a paraffine base,* and to yield the following percentages of distillates in the laboratory:

Naphtha.....	9.1 %
Water-white oil.....	55.0
Solar oil	13.6
Heavy distillate, asphalt, water and loss	22.6

The total production of the State in 1904 was 22,241,413 barrels, making it rank after California, and second in its pro-

*loc. cit.

†C. F. Mabery & D. M. Buck, "On the Hydrocarbons in Heavy Texas Petroleum." J. Am. Chem. Soc., 1900, 22, 553.

C. F. Mabery, "Composition of Texas Petroleum." J. Am. Chem. Soc., 1901, 23, 264.

Clifford Richardson, "Notes on Texas Petroleum." J. Soc. Chem. Ind., 1900, 19, 121.

Clifford Richardson & E. C. Wallace, "Petroleum from the Beaumont, Texas, Field." J. Soc. Chem. Ind., 1901, 20, 690.

Clifford Richardson & E. C. Wallace, "On the Occurrence of Free Sulphur in Beaumont Petroleum." J. Soc. Chem. Ind., 1902, 21, 316.

W. B. Phillips, Texas Petroleum, 1900. The University of Texas Mineral Survey, Bulletin No. 5, December, 1902.

F. C. Thiele, "Texas Petroleum," Am. Chem. Jour. 1899, 22, 489.

duction in the United States, although third as a field. In the value of its output it was sixth.

The petroleums from the Beaumont, Corsicana and Sour Lake fields have been examined in some detail by several investigators.†

Corsicana Field: The petroleum of the Corsicana field is of two kinds, heavy and light oil, the lighter having a gravity of .8459 to .8235, 35.5° to 40.0°B., while the heavier is much denser.

The writer, in 1900, examined the lighter oil from the field, obtained at a depth of about 1,050 feet, with the following results:

CORSICANA OIL.

Specific gravity, 20/20°	.8457
Beaumé	35.5°
Flash	Ordinary temp.
Volatile 100°	10.8% (Naphthla)
“ 160°, 7 hours	35.7
“ 200°, 5 hours	<u>11.2</u>
Total	57.7

Residue after heating at 160° flows readily at 21°. Has the appearance of containing paraffine. After heating to 200°, residue has a quick flow at 25°.

Original oil distilled at 25 mm. Pressure.

Fraction	% Dis-tilled	Color	Sp.Gr. 20/20°	Refractive Index at 20°
Crude oil	—	Dark-reddish-brown, green fluorescence	—	—
Atmos. 57-160°	4.0	Colorless	.7396	1.415
25 mm. 53-90	6.2	“	.7611	1.423
90-118	7.4	“	.7829	1.436
118-151	10.4	“	.8018	1.447
150-175	10.8	“	.8187	1.458
175-180*	5.0	“	.8368	1.464
Residue	50.8	Reddish-brown	.8968	—
Loss	5.4	Paraffine	—	—

* Cracking begins.

Distilled at 25 mm. Pressure after Treatment.

Fraction	Color	NaOH	H ₂ SO ₄	Sp Gr. Loss with 20/20°	Refractive Index at 20°
Atmos. 67-160°	Colorless	3.5%	2.9%	.7337	1.417
25 mm. 58-90	“	2.6	2.3	.7597	1.430
90-118	“	3.1	2.2	.7796	1.438
118-151	“	1.2	1.4	.7939	1.445

151-175	"	3.1	3.0	8132	1.458
175-180	"	4.2	7.2	.8353	1.464
Residue	Light reddish-brown, green fluorescence	—	15.8	.8960	1.494

It appears that this oil is slightly denser than that from the Ohio field, contains paraffine scale, and that the lighter distillates are of a character suitable for illuminants, corresponding with similar components of Ohio oil. This petroleum is, in fact, refined in large amounts most satisfactorily.

According to Thiele* the distillates obtained from it are:

	Distillates.	Sp. Gr.
Naphtha.....	10.8 %	.710
Kerosene	54.5	.796
Residue	34.7	.905

The residue of the Corsicana oil contains paraffine scale but is to a large extent asphaltic. None of the distillates, however, separate any paraffine in a freezing mixture.

An examination of the residue by the writer, according to the method which has been previously described, resulted as follows:

CORSICANA RESIDUUM.

Physical Properties.

Specific gravity, 25/25°.....	.9473
Flash	204°

Chemical Characteristics.

Loss, 160°, 7 hours.....	2.6 %
Character of residue.....	Soft.

Loss 200°, 7 hours (fresh sample).....	7.0 %
Character of residue.....	Soft.

Bitumen insoluble in 88° naphtha, air temperature—pitch.....	6.9 %
Per cent. of soluble bitumen removed by H ₂ SO ₄	16.8

Per cent. of solid paraffines.....	4.8 %
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Residue left after heating at 200° for 12 days.....	72.6 %
Penetration of residue at 25°.....	45

The residuum contains decidedly less paraffine scale than Eastern, Colorado or even Kansas oils, but contains about the same amount of stable hydrocarbons unattacked by acid.

*loc. cit.

The Sour Lake field produces a much denser oil, .9722 to .9211, 14.0° to 22.0°B. A sample of gravity .9459, 18.0°B., obtained in 1900, has been examined by the writer with the following results:

SOUR LAKE OIL.

Specific gravity, 20/20°	.9458 (Contains water)
Beaumé	18.0
Volatile, 100°	22.8%
Character of distillate.	Water with trace of oil.
Volatile, 160°, 7 hours (dry oil)	12.6%
" 200°, 5 hours	<u>14.4</u>
Total	49.8

Residue after heating to 160°, flows readily at 21°, asphaltic, pulls to a long string. After heating to 200°, residue flows quickly at 25°.

Result of Distillation of Original Oil at 25 mm pressure
after removing water.

Fraction	% Dis- tillate	Color	Sp.Gr. 20°	Refractive Index
Crude oil	—	Reddish-brown, green fluorescence	—	—
100-150°	6.6%	Light yellow	.8693	1.474
150-170	12.7	Light green-yellow	.8957	1.489
170-175*	2.6	" " "	.9056	1.500
Residue	78.1	Reddish-brown maltha very sticky	—	—

* Cracking begins.

The fractions showed no paraffine at 0°. The residue appears free from paraffine and is strongly asphaltic.

Result on Treatment with Reagents.

Fractions	Color	Loss with		Sp.Gr. 20°	Ref. Ind. 20°
		NaOH	H ₂ SO ₄		
100-150°	Colorless	3.0%	1.5%	.8623	1.475
150-170	"	1.7	3.2	.8879	1.490
170-175	"	5.0	10.0	.8960	1.495
Residue	Light-reddish brown	—	18.2	.9432	1.521

In an open dish 35% of this oil was volatile in seven hours at 200°, leaving a soft asphaltic residue, but on distillation under a pressure of 25 mm. but 21% was volatilized before cracking began. No paraffine could be separated from the distillates, and that boiling between 100 and 150°, at 25 mm., had the following ultimate composition:

Carbon	85.9 %
Hydrogen	14.0

This is a much larger percentage of hydrogen than is present in the asphaltic oils of California. A comparison of the distillates from the Corsicana, Sour Lake and California oils is of interest :

SPECIFIC GRAVITY.

	Distillate at 25 mm.		California.	
	Corsicana.	Sour Lake.	Fullerton Oil.	
	Before treat- ment.	After treat- ment.	Before treat- ment.	After treat- ment.
50-100°	.7611	.7337	.8745	.8169
100-150	.7932	.7853	.9195	.8593
150-175	.8187	.8132	.9547	.8774

The hydrocarbons of the same boiling point in California oil are of an enormously higher density than either of the Texas distillates, thus differentiating them very sharply, while this is emphasized by the character of the residuum of the different oils, that from California being much less stable than the Texas residuum.

Percent of Residuum in Naphtha Solution Removed by Strong H_2SO_4 .

Fullerton, 1899.....	33.8 %
Summerland, 1894.....	25.8
Sour Lake, 1899.....	18.2
Corsicana, 1899	15.8
Ohio, 1897	13.6
Pennsylvania, 1897	10.5

Since 1900 the Sour Lake oils have been sunk to a greater depth and a much lighter oil obtained than that examined by the writer. The character of the petroleum from this field may, to-day, be of somewhat different nature.

A petroleum which has attracted a great deal of attention is that from the celebrated Beaumont field, or Spindle Top pool, in Jefferson County. This has been examined by many chemists and in some detail by the writer. His results are as follows, in comparison with those for Pennsylvania petroleum :

ULTIMATE COMPOSITION.

	Beaumont, Texas.	Pennsylvania*
Carbon	85.03 %	86.10 %
Hydrogen	12.30	13.90
Sulphur	1.75	.06
Oxygen and Nitrogen.....	.92	
Loss on treatment with excess of H_2SO_4 .	39.0 %	21.0 %

*Engler.

PHYSICAL PROPERTIES.

	Beaumont.	Pennsylvania.
Specific gravity, 25/25°.....	9.12 .9.14	.8014
Flash	Ord. temp. 43°	Ord. temp.
Viscosity	75''	37''

VOLATILITY IN OPEN DISH.

110° 7 hours.....	19.19 %	20.0 %	47.3%
160° " 	21.21	27.0	58.0
205° " 	57.57	49.0	68.0
To Constant Weight:			
105° 42 hours.....	48.0	48.0	58.7
160° 70 " 	64.0*	57.0	71.8†
205° 49 " 	74.0	74.0	84.0
*49 hours. †42 hours.			

VISCOSITY OF RESIDUES.

205°, 7 hours	Quick flow.	Quick flow.	Soft.
205°, 49 hours	Solid.	Solid.	Brittle pitch.
Penetration.....	10	8	

DISTILLATION—ENGLER'S FLASKS.

	Beaumont.	Pennsylvania.
Distillation begins.....	110°	80°
Below 150°.....	2.5 %	21.0%
150-300	40.0	41.0
300-350	20.0	14.0
350-400	25.0	23.0
Loss on acid treatment (150-300 fraction)....	10.0	1.8
250-260	30.0	....
Loss on acid treatment	8.0	....
Percentage of acid used.....	7.0	2.5

SPECIFIC GRAVITY AND REFRACTIVE INDEX.

	Beaumont.	Pennsylvania.
Below 150°.....	Amount too small.	.7188 1.415
150-300.....	.8749 1.473	.7984 1.437
300-350	.9084 1.501	.8338 1.462
350-400.....	.9182 1.508	Paraffine. 1.470

AFTER ACID TREATMENT.

150-300°	.8704	1.473	.7791	1.438
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The residue, amounting to 9.9% of the original oil, was evaporated in an open dish to 6%—it was then a brittle pitch which had the following properties:

Specific gravity, 25/25°	1.0454
Color	Black
Lustre	Shiny
Structure	Massive
Fracture	Conchoidal
Hardness—penetration	15

Bitumen soluble in CS ₂ , air temperature	99.8 %
Organic matter insoluble	.1
Inorganic or mineral matter	.1
	100.0

Soluble in 88° naphtha, air temperature	60.0 %
Per cent. of total bitumen soluble	60.1

Soluble in 62° naphtha	64.8 %
Per cent. of total bitumen soluble	64.9
Bitumen yields on ignition:	
Fixed carbon	21.13

A similar, but softer pitch, made by boiling crude oil for twenty hours in an open dish, had the following properties, as compared with a "D" grade residue, or paving asphalt, from Los Angeles, California, oil.

	Beaumont, Texas.	Los Angeles, California.
Penetration at 25°	78	78
Specific gravity, 25/25°	.9943	.9964
Bitumen soluble in 88° naphtha, air temp.	78.3%	74.4%
Bitumen soluble in 88° naphtha, ...	84.3%	81.6%
Fixed carbon	8.7 %	15.0 %

FRACTIONAL DISTILLATION.

Fraction.	% Dis- tillate.	Sp. Gr. 26°	Refractive Index.
Atmos. Pres.:			
149-205°	1.0 %	.8114	1.459
205-227	8.4	.8408	1.461

August, 1906.]	<i>Petroleums of North America.</i>		115
227-249	4.4	.8569	1.467
249-271	10.8	.8705	1.476
271-293	10.8	.8863	1.485
293-317	13.1	.9009	1.492
20 mm. Press.:			
200-240°	13.0	.9184	1.505
240-280	8.8	.9349	1.514
280-320	10.6	.9429	1.521
Total	80.9		
Residue, heavy, slow flow at 21°.			
Difference in boiling point for 760 mm. pressure 117°.			

EFFECT OF REAGENTS ON DISTILLATES.

Fractions.	Removed.	Specific Gravity after treatment.	Refractive Index 20°
	Excess of strong H ₂ SO ₄ .		
205-227°	7.7 %	.8357	1.463
249-271	17.8	.8497	1.474
293-317	21.6	.8929	1.486
	Excess of H ₂ SO ₄ + HNO ₂ after H ₂ SO ₄ .		
293-317°	11.0	.8879	1.483
Total oil removed by reagents, 32.6 %			

EXAMINATION OF THE PRECEDING RESULTS.

From the preceding results it appears, although the two specimens are slightly different in their specific gravity and flash point, that the Beaumont oil has a very high density for one beginning to distill at 110°, and that the hydrocarbons of which it is composed, as shown by the ultimate composition of the original oil, and by a comparison of the specific gravity and refractive index of the 150-300° distillates from the Engler flasks with similar distillates from Eastern oils, must belong largely or entirely to some series other than the paraffine, and probably to the same series as those found in the Sour Lake petroleum which we have previously examined (J. S. Chem. Ind., 1900, 19, 121.), rather than those of the Corsicana oil, which consists largely of paraffines. It is also plain that the oil contains a much larger proportion of unsaturated hydrocarbons removable by sulphuric acid than Pennsylvania petroleum. The Beaumont oil has a high sulphur content and carries, as it comes from the wells, a large amount of hydrogen sulphide in solution. This gas has previously been observed

in solution in petroleum, but not in so large quantity as at Beaumont. The sulphuretted hydrogen is largely lost on standing and more completely on blowing air through it. After such treatment the oil contained 1.75% of sulphur in the form of sulphur derivatives of the hydrocarbons, and as free sulphur.*

Mabery† has examined in detail fractions of this oil where heaps occur at certain temperatures on continued distillation, with the following results:

Fractions.				Distillates.	
760 mm. Pressure:					
145-200°				4.0 %	
200-250				11.0	
14 mm. Pressure:					
95-100°				17.0 %	
150-200				17.0	
250-300				51.0	
Residue				15.0	
				100.0	
Fraction.	Symbol.	Sp. Gr. 20°	Carbon.	Hydrogen.	Ref. Ind.
130-135°	C ₁₂ H ₂₂	.8553	86.86 %	13.27 %	.....
155-160	C ₁₄ H ₂₈	.8746	86.26	13.48	1.473
190-195	C ₁₆ H ₃₂	.8915	87.26	12.54	1.484

It appears that these hydrocarbons belong to the C_nH_{2n-2} series and undoubtedly, at higher boiling points, are of the C_nH_{2n-4} series.

The heavy fluxes, or oily residuums from Beaumont oil, where the distillation is stopped before the production of a residual pitch, have the following characteristics:

HEAVY RESIDUUM—BEAUMONT, TEXAS.

PHYSICAL PROPERTIES.

Specific gravity, 25/25°.....	.9735
Flash	214°

CHEMICAL CHARACTERISTICS.

Loss, 160°, 7 hours.....	.8 %
Character of residue.....	Soft.
Loss, 200°, at 7 hours (fresh sample).....	6.2 %
Character of residue.....	Soft.

*J. Soc. Chem. Ind., 1902, 21, 316.

†loc. cit.

Bitumen soluble in CS ₂ , air temperature.....	99.6 %
Organic matter insoluble.....	.4
Inorganic or mineral matter.....	.0
	100.0

Bitumen insoluble in 88° naphtha, air temperature—Pitch.....	4.8 %
Per cent. of soluble bitumen removed by H ₂ SO ₄	20.9
Per cent. of total bitumen as saturated hydrocarbons.....	79.4

Per cent. of solid paraffines..... .1.7

Fixed carbon 3.5 %

On comparing this residuum with that prepared from California oil it is seen to be less dense and to differ from it in such a way as to show that the hydrocarbons of which the two are composed are quite different. It is worthy of note that it contains an appreciable percentage of solid paraffines. The Beaumont petroleum, therefore, contains not only the hydrocarbons of the various polymethylene series but also some of the C_nH_{2n+2} series.

As the oil is distilled industrially, a much larger percentage of residual pitch is obtained than by gradual distillation at reduced pressures in the laboratory, in which respect the oil differs entirely in its behavior from that from California fields, where a much smaller percentage is obtained industrially. The industrial pitch has the following characteristics:

RESIDUAL PITCH FROM TEXAS, BEAUMONT, OIL.

PHYSICAL PROPERTIES.

Specific gravity, 25/25°.....	1.0803
Color of powder or streak.....	Black
Lustre	Lustrous
Structure	Uniform
Fracture	Semi-conchoidal
Hardness, original substance.....	-1
Odor	Asphaltic
Softens	110°
Flows	119°
Penetration at 25°.....	13

CHEMICAL CHARACTERISTICS.

Loss, 160°, 7 hours.....	.13 %
Character of residue.....	Smooth

Loss, 200°, 7 hours (fresh sample).....	.19 %
Character of residue.....	Smooth
Bitumen soluble in CS ₂ , air temperature.....	99.0 %
Organic matter insoluble.....	.8
Inorganic or mineral matter.....	.2
	100.0

MALTHENES:

Bitumen soluble in 88° naphtha, air temperature.....	65.4 %
This is per cent. of total bitumen.....	66.1
Per cent. of soluble bitumen removed by H ₂ SO ₄	32.1
Per cent. of total bitumen as saturated hydrocarbons.....	44.8

Bitumen soluble in 62° naphtha.....	71.5 %
This is per cent. of total bitumen.....	72.2

CARBENES:

Bitumen insoluble in carbon tetrachloride, air temperature.....	5.1 %
---	-------

BITUMEN YIELDS ON IGNITION:

Fixed carbon	24.0 %
Paraffine scale	1.2 %

It is of interest to compare this residual pitch with that prepared from California petroleum. Its most striking characteristic is the presence of from one to 2% of paraffine scale, derived from the original oil. The percentage of fixed carbon which it yields is considerably higher than is obtained with the California petroleum, although a higher percentage would be found in the latter were the distillation carried to the same extremity. It contains a larger percentage of hydrocarbons unattacked by acid.

OTHER FIELDS.

Petroleums from some of the other fields in Texas resemble in part that from the Corsicana field, and more that from the Beaumont field. The heaviest oils are, however, quite widely distributed, especially in the shallower wells. In the Saratoga district the oil is of a density of from .9722 to .9333, 12.0 to 20.0°B.; in the Batson Prairie district .9150 to .9091, 23.0 to 24.0°B.; in the Matagorda pool .9396 to .9333, 19.0 to 20.0°B.; while the lighter petroleums .9150 to .8140, 23.0 to 42.0°B.,

are found in the South Basque, Henrietta, Batson Prairie and a few minor districts. None of these oils has been examined in detail.

From the preceding data it appears that there is a very great variation in the character of the petroleum which is produced in Texas. All of the Texas oils contain some paraffine scale and in all cases leave a larger or smaller amount of asphaltic residue. The heaviest petroleum, however, differ essentially in the character of their higher boiling hydrocarbons, from California oil.

KANSAS FIELD.

The Kansas oil field covers a large area and extends into Oklahoma and Indian Territories. The petroleum is of very varied character, but much of it has a density of .8750, 30.0°B., and less, and is very desirable for refining purposes. About one million barrels was the output of 1903, but development has been so rapid that this exceeded 4,500,000 barrels in 1904 in Kansas alone, while over 1,300,000 barrels were produced in Indian Territory and Oklahoma in that year. The wells are from 350 to 1,500 feet deep and the oil is found in sands whose horizons are not known to the writer. It would seem that eventually this field will be connected with that of Texas.

A typical Kansas oil of .8750 gravity, 30.0°B., received in 1901 from the Federal Gas & Oil Company, Cherryvale, Montgomery County, was examined by the writer with the following results:

Specific gravity, 25/25°	.873
Flash	32°
Volatile, 105°, 7 hours	21.4%
" 160°, 7 " (fresh sample)	33.6
" 200°, 7 " (" ")	47.9
Character of residue at 200°	Soft
Volatile, 160°, to constant weight	47.4%
Character of residue	Soft
Volatile at 200°, to constant weight	59.4%
Character of residue	Soft—paraffine

Distillation in vacuo 20 mm. Pressure.

Fraction	% Dis- tillate	Sp.Gr. 20°	Ref. Index	Remarks
60-80°	3.2	.7637	1.425	Light straw color
80-100	2.8	.7683	1.428	" " "
100-120°	4.3	.7814	1.434	" " "
120-140	6.0	.8008	1.443	" " "
140-160	8.1	.8209	1.454	" " "
160-180	5.1	.8382	1.462	" " "
180-200	5.7	.8489	1.469	" " "
200-220	7.0	.8608	1.475	" " "
220-240	5.1	.8911	1.482	Solid 10° Crystalline paraffine
240-260	6.2	Boiled over		do.
260-280	12.5	" "		Rich in paraffine
280-300	4.2	.8963	1.498	Solid

The higher distillates in this oil separate paraffine and the residue is of a distinctly paraffine nature. The distillates correspond in character to those obtained from the Trenton limestone petroleum of Ohio, and show that the hydrocarbons contained in the oil must, in addition to the paraffines, consist of the same series found in the latter oil, that is to say, the C_nH_{2n-2} and C_nH_{2n-4} series.

These oils are collected by the pipe lines and refined at Neodesha, Kansas, while additional lines now carry them to Whiting, Indiana, for treatment at the refineries of the Standard Oil Company. The characteristics of the residuum produced at the Neodesha refinery are as follows:

PHYSICAL PROPERTIES.

Specific gravity, 25/25°	.9328
Beaumé	20.5
Color	Brown
Odor	Petroleum
Flash	196°

CHEMICAL CHARACTERISTICS.

Loss, 160°, 7 hours.....	2.6 %
Character of residue.....	Soft.
Loss, 200°, 7 hours (fresh sample).....	5.7 %
Character of residue.....	Soft.

Bitumen insoluble in 88° naphtha, air temperature—Pitch.....	3.6 %
Per cent. of soluble bitumen removed by H_2SO_4	14.4
Per cent. of solid paraffines.....	7.8 %
Fixed carbon	4.1 %

The residue from the distillation of Kansas oil reveals its mixed character by the paraffine scale which it contains and the higher fixed carbon which it yields.

The Kansas oil is becoming an important factor in the petroleum industry in the United States. The wells have very considerable staying qualities and some of those in the territories are large producers even as compared with some of the gushers of the old eastern fields. It is, of course, denser than any of the eastern petroleum, as a rule, but differs from the Ohio oil in being comparatively free from sulphur compounds. Like the Ohio oil the higher distillates are very rich in paraffine scale.

LOUISIANA FIELD.

Within the last four years Louisiana has made a decided record as a petroleum producing State, the output for 1904, 6,611,419 barrels, making it the eighth in rank among the producing States, while but a little over half a million barrels were produced in 1902.

Petroleum has been found at a number of points in the State but the principal field is at Jennings, and twelve miles west of there, which is known as the Welsh field. The other localities have not been largely developed.

The production of the Jennings field in 1904 was 2,905,507 barrels, while that of the Welsh field was over 35,892 barrels, and this has been largely increased since that date, amounting to sixty thousand barrels per day at the beginning of 1905. The oil occurs in similar geological horizons as that of Texas, and the two fields may be considered as virtually one.

The petroleum has been examined by Charles E. Coates and Alfred Best* who present the following data:

*J. A. Chem. Soc., 1903, 25, 1153.

	Texas.	Louisiana.		
	Beaumont.	Welsh.	Jennings.	Beaux Bridge.
Sp. Gr., 25°	.9228	.9276	.9093	.9392
Distillation, Engler Flask, 760 mm. to -150°	None.	None.	None.	None.
150-200	2 %	"	"	"
200-250	8	2 %	13 %	1 %
250-300	26	17	28	15
300-350	26	23	24	22
Estimated depth of well (feet)	1200	700(?)	1000	600
% of sulphur in crude oil.	1.95	0.32	0.39	0.20

It appears from the preceding data that the Louisiana oil carries much less sulphur than the Beaumont oil and that the Jennings oil is of a lower density and gives a greater percentage of distillates below 300°. Denser oil occurs outside of the Jennings field. In the latter, distillates have been isolated consisting of the C_nH_{2n-2} and C_nH_{2n-4} series of hydrocarbons corresponding to the following formula and having the following specific gravity and boiling point:

Oil from Jennings Field. 60 mm. Pressure.

Fraction	Symbol	Specific Gravity
110-115°	$C_{12}H_{22}$	.8479
160-165	$C_{14}H_{26}$	.8785
210-215	$C_{17}H_{30}$	.9009

The distillation of the lowest boiling point is characterized by an odor strongly resembling turpentine, so that it is sold as a turpentine substitute.

Coates and Best have also examined the distillates from the Jennings and Welsh oils boiling below 300°. In the Jennings oil three fractions were obtained which, after treatment with H_2SO_4 , have the following characteristics:

Oil from Jennings Field.

Fraction	Pressure	Symbol	Sp.Gr.	Ref. Ind.	Remarks
110-115°	80 mm.	$C_{11}H_{20}$	.8373	1.4535	Odor of turpentine
150-155	"	$C_{13}H_{24}$	.8649	1.4692	No odor
200-205	"	$C_{16}H_{28}$	.8801	1.4805	—

Oil from Welsh Field.

145-150°	80 mm.	C ₁₂ H ₂₂	.8551	1.4662	---
165-170	100 "	C ₁₃ H ₂₄	.8679	1.4666	---
175-180	33 "	C ₁₇ H ₃₂	.8736	1.4760	---

The second fraction from both of these oils agrees quite closely in their characteristics with that from the Summerland, California, oil of corresponding boiling point separated by Mabery.

	Fraction.	Pressure.	Sp. Gr.	Ref. Ind.
Summerland, Cal.	150-155°	60 mm.	.8621	1.4681
Jennings, La.	150-155 %	80 "	.8649	1.4692
Welsh, La.	165-170 %	100 "	.8679	1.4666

All the fractions consist of hydrocarbons which have a composition corresponding those of the C_nH_{2n-2} series, with the exception of the third, from Jennings oil, which is less rich in hydrogen and corresponds in composition to one belonging to the C_nH_{2n-4} series.

In another very heavy oil having the following characteristics, from Bayou Bouillon, similar distillates were examined by Coates:

Specific gravity	.9669
Distillation begins	275°
Fraction at 300°	11.0 %
Sulphur	.57 %

Fraction.	Pressure.	Sp. Gr.	Ref. Index.	Symbol.
140-145°	33 mm.	.8557	1.4691	C ₁₃ H ₂₄
170-175	"	.8871	1.4820	C ₁₄ H ₂₈
190-195	"	.8966	1.4883	C ₁₇ H ₃₀
200-205	"	.9006	1.4916	C ₁₈ H ₃₂
225-230	"	.9104	1.4972	C ₁₉ H ₃₄

With the exception of the first fraction these distillates contain hydrocarbons belonging to the C_nH_{2n-4} series.

It is evident that the Louisiana petroleum, except in the smaller amount of sulphur which it contains, has a very considerable resemblance to Beaumont oil, and this is not surprising when the geographical and geological location of the two fields is considered.

ALASKA FIELD.

Petroleum has been found in a number of localities in Alaska, the most important of which are known as the Con-

trollers Bay, Cook Inlet and Cold Bay fields,* but nothing of industrial importance has been developed in any of them, although a number of wells have been sunk at various points.

A seepage from Cold Bay, Cook Inlet, in 1903, was found by the writer to have a density of .989, 11.6°B. It left on heating 72.3% of an asphaltic residue, having a penetration of 27, which contained 2.7% of paraffine scale solid at 40°, and yielded 12% of fixed carbon on ignition. Such petroleum corresponds closely to some of those found in Texas. In the publication cited, data in regard to petroleum from the same field are given, which are of some interest.

Report of Tests of Oil from Oil Bay and Cold Bay.

	Oil Bay	Cold Bay
Specific gravity at 16°	.9557 = 16.5°B.	.9547 = 16.6°B.
Distillation by Engler method :		
Initial boiling point.	230°	225°
Burning oil (distillation up to 300° under atmos. pressure).	13.2% = 25.9°B.	13.3% = 29.6°B.
Lubricating oils (spindle oils 120 mm. pressure up to 300°).	39.2 = 22.6°B.	28.3 = 23.8°B.
Lubricating oils (120 mm. pressure, 300-350°).	19.6 = 16.9°B.	18.3 = 18.0°B.
Paraffine oils (by destructive distillation under atmospheric pressure).	22.4 = 20.4°B.	32.0 = 20.4°B.
Coke and loss.	5.6	8.1
Total sulphur.	.098	.116

These data fail to bring out the fact that the oils are largely of an asphaltic nature, but show that the percentage of sulphur is not large. The initial boiling point is, in both oils, very high, and this, together with the high density, would point to the fact that they can never be of great industrial importance as far as the production of illuminants is concerned.

Petroleum from other localities in Alaska have not been examined as far as the writer is aware, but they are probably of the same character as that from the Cold Bay field.

CUBAN FIELD.

The native bitumens occur widely scattered over the Island of Cuba, but industrially, only the solid forms have been de-

*Report on Progress of Investigations of Mineral Resources of Alaska in 1904, Washington, Government Printing Office, 1905.

veloped, grahamite and asphalt. Indications of petroleum have been found in all the Provinces with the exception of Puerte Principe, and various attempts have been made to sink wells, but so far without results. In the Province of Santa Clara there is an occurrence of extremely light oil. At the Motembo well a colorless naphtha occurs which it is difficult to believe is a natural product. Near the town of Santa Clara an amber-colored petroleum of specific gravity .901, 25.4°B., is found floating upon the surface of a stream of water, having an agreeable odor, like cedar wood. Most of the petroleums in Cuba, however, are extremely dense or in the form of maltha, having an asphaltic base, and a density of from .95 to 1.05, 17.4° to 10.0°B. A number of samples of this material have been examined by the writer. The following are data characteristic of one of these malthas:

MALTA FROM HATO NUEVO, MATANZAS PROVINCE, CUBA.

Specific gravity, 25/25°.....	1.0466
Loss 100° to constant weight.....	6.2%
Consistency of residue.....	Soft.
Loss 160°, 7 hours.....	6.8%
Penetration of residue at 25°.....	55
Loss 200°, 7 hours (fresh sample).....	11.9 %
Penetration of residue at 25°.....	18
Bitumen soluble in CS ₂ , air temperature.....	98.6%
Organic matter insoluble.....	.7
Inorganic or mineral matter.....	.7
	100.0
Per cent. of total bitumen:	
Soluble in 88° naphtha, air temperature.....	75.5%
Soluble in 62° naphtha.....	83.7
Fixed carbon	11.0 %

A lighter oil is found in Santa Clara Province having the following characteristics:

Specific gravity, 25/25°	.944
Beaumé	18.3°

Loss 100° for 1 hour.....	1.5 %
Total loss 160°, 7 hours.....	18.5 %
Character of residue	Soft.

None of the petroleums of Cuba can be of great industrial importance for the production of illuminants and, although it is not impossible that material may be obtained in large quantity after proper exploitation, it would prove, in all probability to be asphaltic and could only be made available for use as fuel.

MEXICAN FIELD.

Indications of the occurrence of petroleum are frequent along the coast line of the Gulf of Mexico, and especially in the neighborhood of Tampico. A large number of samples of this material have been examined by the writer and found to be of very great density and of an asphaltic nature, in this respect resembling the oil found in Cuba. The character of the petroleum, in general, is revealed by the following data:

PETROLEUM FROM WELL AT CHAPAPOTE.

Specific gravity, 25/25°.....	.9604
Loss at 110°.....	10.4 %
“ “ 160	23.4
“ “ 200	6.8
Penetration of residue at 150°.....	70
“ “ “ 200°	18
Bitumen soluble in CS ₂ , air temperature.....	99.8 %
Organic matter insoluble.....	.1
Inorganic or mineral matter.....	.1
	100.0

While lighter oil may be developed on further exploitation, it is evident that the petroleum of Mexico can never be relied upon for the production of highly valuable products, although it may eventually be found in quantity for use as fuel.

COMPARISON OF NORTH AMERICAN PETROLEUMS.

From the preceding data it appears that the petroleums of North America are of a most varied and interesting character. Those of the earlier days of the industry, from the Appalachian

field, were paraffine oils and on this account, and their freedom from sulphur, have been the most valuable obtained in the United States, or in any other part of the world, for the production of illuminants. Although the supply from this field forms a very much lower percentage in the total production of the United States than it has heretofore and, although the production of the field has somewhat diminished, the value of the latter is greater than that of any other field and it will probably occupy this position for many years to come, since it is becoming extended from year to year and new pools are being developed, as is illustrated by the great increase in the production of West Virginia and Kentucky within the last few years.

The petroleum of North-western Ohio and Canada which next appear upon the scene chronologically, being sulphur oils, were far less valuable, not only on this account, but because of the smaller percentage of illuminants, until a process of distillation with copper oxide was discovered which made it possible to secure a satisfactory article. The Ohio field, of late years, has extended into Indiana and is of great importance, not only as regards the value of its products, owing to the possibility of making paraffine illuminants from it, but also on account of the number of barrels produced, in which, in 1904, it ranked third among the North American fields, with 21% of the total production.

Within the last ten years, the development of new fields has modified very largely the aspect of the petroleum industry in North America. California, which produced less than 5% of the entire supply of oil in 1899, in five years has more than quintupled that amount. This oil, however, is composed of such a series of hydrocarbons, of a non-paraffine nature, that its value is comparatively small, being nearly one-third less than that of the oil obtained from the Appalachian field. It does not offer a distillate which is satisfactory as an illuminant when burned by itself.

The oils from the more recently developed fields of Kansas and Texas are of variable character. Although all are more or less asphaltic, they also contain varying proportions of paraffine hydrocarbons, and the lighter oils are proving a vast source of supply of illuminants of a paraffine nature, which

will, no doubt, continue to increase in importance in the future. The more asphaltic oils of the Gulf Coastal Plain of Texas and Louisiana are so strongly asphaltic as to be of value only for the production of lubricants, for use as fuel and as gas oil. They yield practically no paraffine illuminants.

It is also worthy of note that no petroleums have been found in North America of the Russian type, that is to say, consisting preponderatingly of monocyclic polymethylenes or naphthenes.

The present aspect of the petroleum industry in the United States is a very satisfactory one. With the diminution of the output of paraffine oils in the Appalachian field, there has been an increase in that from the Indiana field, which makes the combined output from the two somewhat larger in 1904 than for that of five years ago, while the strongly paraffine petroleums of the new Kansas and some individual Texas fields have also added to the source of supply of desirable illuminants to such an extent as to be a matter of great importance, and to make the outlook for a continued supply of burning oil at the present time encouraging. The petroleum industry, however, is so kaleidoscopic that it is impossible to say whether there will be as great a change in the aspect in the next five years as there has been in the past. It will be a matter of interest to watch the development which may occur.

Long Island City, New York,

March 15, 1906.

THE MOST POWERFUL LOCOMOTIVE.

What is said to be the heaviest passenger engine ever built has been delivered to the Lake Shore & Michigan Southern Railroad. It weighs 244,700 pounds, of which 170,000 are on the driving wheels. The engine and tender weigh 403,700 pounds and the capacity for water is 7800 gallons, while that for coal is fifteen tons. This powerful locomotive was designed as a step in the development of large passenger locomotives on the Lake Shore road, which began about seven years ago, as a result of which this road has a series of successful designs. The Walschaert gear has been generally adopted because of favorable experience in both freight and passenger service. The new locomotive is entirely free from untried devices or principles.

Mechanical and Engineering Section.

(*Stated Meeting, held Thursday, April 5th, 1906.*)

The Design, Installation and Maintenance of the Modern Office Building.

BY CHAS. GOBRECHT DARRACH, C.E., ETC.

(*Concluded from vol. clxii, page 56.*)

SANITATION.

In discussing the subject of sanitation, we must consider not only the purity of the air we breathe and of the water we drink, but also that temperature at which they are best adapted for comfort and health. We must also consider the proper disposal of vitiated air and water or their revivification.

In community buildings as in most private dwellings the imperative problem of proper sanitation is ignored probably more flagrantly than any other.

The system of cleansing has in the past followed the old methods of manual labor. We have now at our command mechanical means, which can be installed not only reducing the cost, but also increasing the efficiency.

In addition, unwholesome and disagreeable odors must be prevented, and stale air replaced with fresh pure air, or the tenants cannot do their work well or with comfort.

It seems like an insult to present day civilization, that this subject should be even mentioned, but (like boiler and engine room conditions) it is systematically neglected, even in the face of both experience and example.

Great stress is laid upon the poisonous effects of the carbon oxides in the atmosphere.

Unfortunately, some recognized sanitararians have minimized

the importance to health, of air free from the other gases of decomposition, and have almost wholly neglected that potent adulteration—an air too highly charged with aqueous vapor.

As an extreme case, but one which, as an example, may be used to illustrate the ill effects of foul air as well as the beneficent results obtained by an improved condition, the speaker would call your attention to an article in the "Engineering Record" of January 22, 1898.

In the institution under consideration the air was so vitiated, that on rising in the morning, the attendants were frequently attacked with violent nausea, and the malodorous atmosphere greeted the visitors at the portal.

The principal cause of the trouble, lay in the vicious design of the toilet hoppers, added to the unscientific system of "vent"ilation.

The toilet hoppers were removed and the sanitary hopper hereinafter described was substituted, as well as other modifications in the ventilation system.

The results, as exhibited in the following quotation, speak for themselves.

PNEUMONIA AND SANITATION.

Philadelphia, Pa., January 8, 1898.

"To the Editor of The Engineering Record.

"Sir: As recorded results are always interesting and instructive, the writer would call attention to certain data obtained after having improved the sanitary condition of a children's asylum constructed within the last few years.

"The institution in question has a constant population of over two hundred children from one and one-half to six years of age, eight to ten infants at the breast, and thirteen adults. The individuals, of course, are constantly changing, so that the mortality noted is not proportionately as great as would otherwise appear. The children are gathered from the lower walks of life, and generally, in poor condition when they are placed in the home, many of them having contracted disease and suffering from bad attention, etc.

"During the first year after the institution had been occupied there were *thirty-eight deaths*; during the second year, *sixty-eight deaths*; during the year after the sanitary conditions had been improved there were but *five deaths*. The character of the children in the institution was about the same, but the population during the last year was somewhat greater than previously. As you will note, there was a notable improvement in the general health conditions.

"Following you will find certain tables showing the number of deaths and the causes of mortality. The first table shows diseases and deaths which have been imported, or those not directly attributable to bad sanitation. The second table shows diseases and deaths ordinarily considered as the result of impure air, etc. The third table shows mortality from pneumonia and throat troubles.

TABLE I.

Mortality from diseases which may have been imported or not directly attributable to bad sanitation.

	1895. Before Improve- ments in Sanitation.	1896. After Improvements in Sanitation.	1897. After Improvements in Sanitation.
Cholera infantum.....	1	2	1
Marasmus	1	10	1
Convulsions	0	4	1
Convulsions and measles.....	2	0	0
Spinal caries.....	0	0	1
Gangrene of face.....	0	1	0
Gangrene of face and measles....	1	0	0
Gangrenous stomatitis	1	0	0
Nephritis	2	0	0
Indigestion	1	0	0
Gastro-enteritis	0	1	0
Tuberculosis	1	1	0
Gastro-intestinal catarrh.....	0	1	0
Total	10	20	4

TABLE II.

Mortality from diseases ordinarily considered as the result of impure air, etc.

Diphtheria and measles.....	8	0	0
Meningitis	4	14	0
Total	12	14	0

TABLE III.

Mortality from pneumonia and throat diseases.

Pneumonia	2	27	1
Pneumonia, catarrhal.....	0	1	0
Pneumonia and measles.....	13	0	0
Membraneous croup.....	0	4	4
Membraneous croup and measles..	1	0	0
Bronchitis	0	2	0

	—	—	—
Total	16	34	1
	—	—	—
Grand total.....	38	68	5

"Whether or not bad sanitation was the cause of the great mortality from pneumonia and throat troubles, I am not prepared to say, but when we find, that in the first year of the building's occupancy (1895), we had sixteen deaths from pneumonia and throat diseases in a total of thirty-eight, or forty-two per cent.; in the second year (1896), after the building had been well saturated, thirty-four deaths in sixty-eight, or fifty per cent., and in the year after the improvements had been made (1897) but one in a total death rate of five, it is fair to presume that either pneumonia and throat troubles may be caused by a bad condition of sanitation, or that recovery is prevented in such cases.

"It is not often that an engineer has the opportunity to obtain data which is herewith submitted, but it seems to me that these facts are worthy of serious consideration by both our own and those of the medical profession."

CHAS. G. DARRACH.

An atmosphere too highly charged with aqueous vapor is unsanitary.

It is hardly necessary, for me to remind you of the increase in the mortality which follows each rise, in the humidity of the atmosphere.

We engineers should know the amount of heat required to vaporize water, and that there is no reason that the damp winds, of February, March and August, should not keep the physicians busy, and enrich the graveyards. The perspiration is not absorbed by an atmosphere saturated with moisture. During the winter months the skin is chilled by this damp, cold envelope, and the circulation of the blood in the capillaries retarded—resulting not only in the congestion of blood in the internal organs, but also in preventing that purification due to skin action so necessary to health.

During the summer the delightful coolness of dry air (even when the thermometer indicates a torrid atmosphere) is produced by evaporation of the imperceptible perspiration, and the sweat of a muggy day converted into a refrigerant both healthful and refreshing.

These phenomena are not difficult of apprehension when we remember that 1000 heat units are required to vaporize one pound of water.

Dry air moreover contains a greater proportion of oxygen than air saturated with moisture, consequently the air used in respiration is of richer quality and more reviving to the blood.

The net result of saturated air is depletion of vitality—from direct blood poisoning—congestion and suffocation.

The exhilarating effects of a dry atmosphere, make cheerful hearts and healthy bodies.

Taking into consideration, the density of the atmosphere, in relation to pressure, the amount of oxygen per cube, is greatest on the surface of the earth at the sea level; the weight of oxygen per cube *decreases* with the rise of temperature, as it does, when the air is contaminated with aqueous or other vapors.

Taking as a standard, dry pure air at 70° Fahr. and at the sea level, as containing one hundred per cent. of oxygen; the air at the same temperature and at elevation of 5,000 feet contains but 80 per cent., and at 10,000 feet but 66 per cent. of oxygen at the sea level at 70° Fahr.

The aqueous vapor, mixed with air, supplants the vitalizing oxygen, in direct proportion to the saturation.

However advantageous, and beneficial, it may be to provide, for the clients in our office building, an equitable temperature throughout the entire year, with an atmosphere not only free from gaseous products of decomposition but also free from an enervating aqueous saturation. The speaker doubts if the general public are as yet sufficiently well informed to demand such a plant.

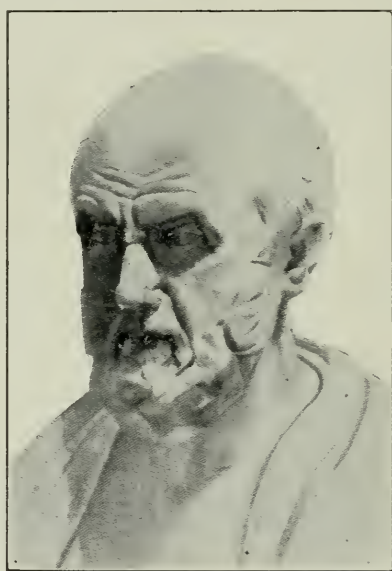
But for auditoriums, sanitoriums and hospitals such conditions should be *enforced*.

Then it would be unnecessary for the physician to send his consumptive patient to the mountains for pure air, free from moisture; but so attenuated that the poor victim, with a weak heart, succumbs to the extra duty demanded. Nature does the best she can with the ghost of the air, respiration becomes more rapid, the heart palpitates, the poor diseased lung and the weak heart have too great a tax. The panacea kills.

In other words suffocation takes place either from an attenuated atmosphere, or from one charged with moisture, as it does when the air is charged with any other poisonous gas; the necessary oxygen not being present.

We, here in Philadelphia, or in any of those cities from which they flee, who can, to escape the torrid and moisture laden air of summer, or the cold and damp Ides of March, could remain at home in the full enjoyment of an atmosphere pure and rich in the life-giving oxygen; if only the knowledge now possessed were utilized.

Are we not slow in this twentieth century A. D.? when we do not emulate the great "Hippocrates," who, thousands of years ago, understood, and used, the beneficent work of a *pure atmosphere* and pure water in his sanitoriums and sun parlors on the lovely island of Cos.

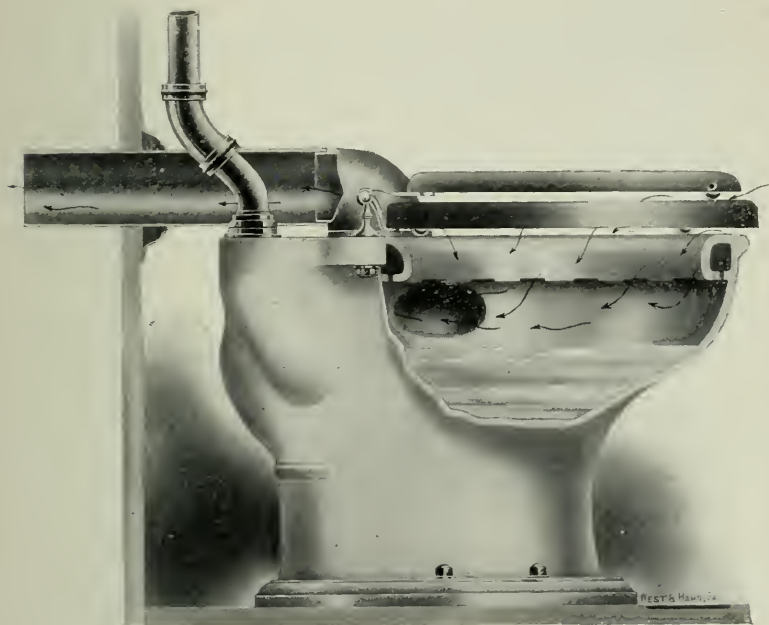


Hippocrates

Referring again to the Drexel Building, 1886-'88, this most important question was studied and all the advantages of the then state of the art utilized. Since then, in 1888, if memory is not at fault, a toilet hopper was made (after designs of the author specified for the plumbing in the Pennsylvania Institution for the Deaf and Dumb, at Mt. Airy, Phila.), which had a seat vent above the water line of twelve square inches area. A draught of air is induced, either by a heated flue or fan from the bowl of the closet, not only preventing the possi-

bility of the escape into the room of any objectionable odors, but of ventilating the room by means of the initial receptacle. This style of toilet hopper was also installed in the Reading Terminal R. R. Station Office Building, in St. Vincent's Maternity Hospital and Children's Home, in the Professional Building, in the U. G. I. Office Building and wherever the speaker's influence was sufficient to induce its adoption.

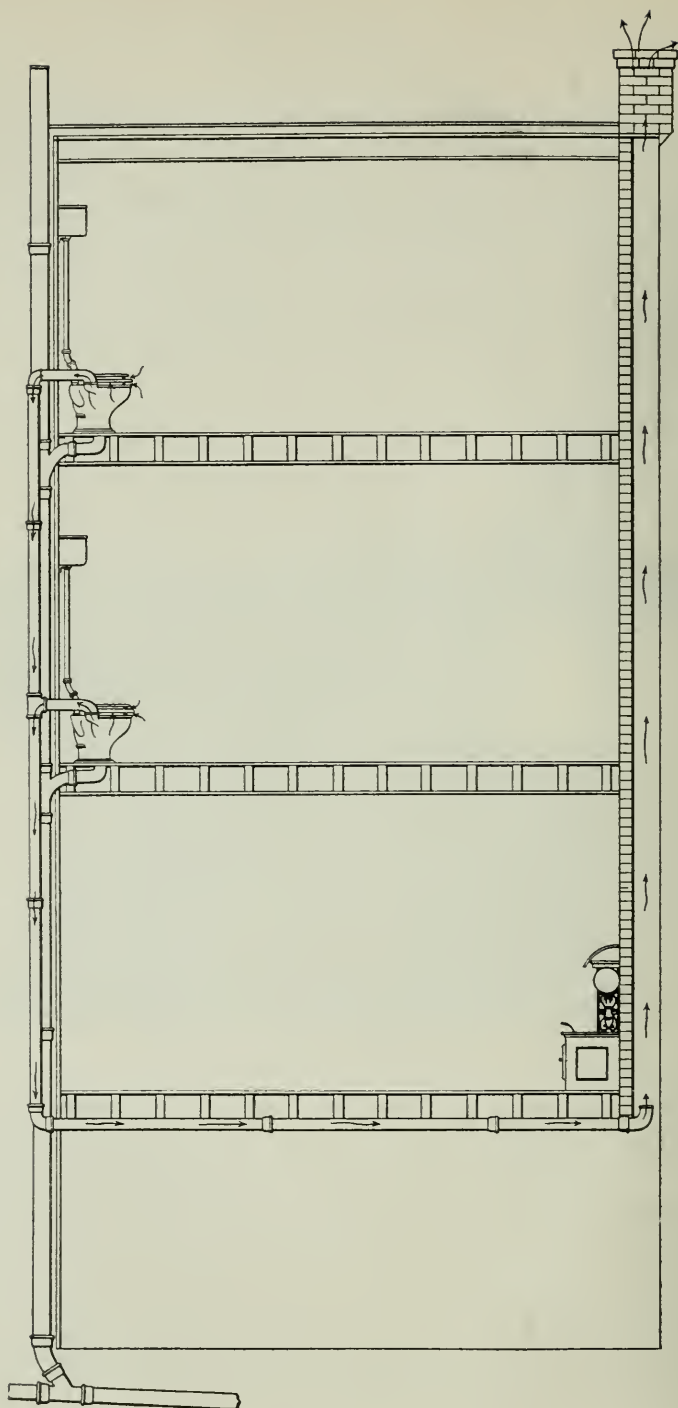
This style of hopper can be installed in private dwellings,



Sanitary Hopper

as shown on accompanying plate, and its use should be enforced by ordinance. It has been on the market eighteen years, but has escaped the notice of sanitarians and municipal authorities. The vent pipes should be carried to the cellar and connected to the kitchen flue—if gas is used in summer a “Bunsen” burner will be sufficient to warm the air and induce the draft.

In the design of all receptacles for decomposing matter, there should always be a sufficient depth of water to submerge the ashes.



Domestic Installation of Sanitary Hopper

The common practice, authorized by our health officers, is to violate both of these sanitary requisites.

SEWAGE DISPOSAL.

It often happens that much of the sewage cannot flow directly to the common sewers, but to be discharged must be raised from their drainage level. The ordinary practice is to conduct all this sewage to a well at a low level and lift it by automatic-pneumatic apparatus to the proper level.

A much less expensive apparatus, operating at a minimum cost, was installed at the U. G. I. Office Building.

This apparatus consisted of discharging the sub-sewage into a septic tank, where the organic wastes were liquefied by natural fermentation and the resultant nearly clear solution pumped to the sewer. This system has been in operation for the past six years without complaint.

The author installed a system of municipal sewage disposal on this principle some twenty years ago, in which the resultant liquefied sewage was discharged into an harbor for pleasure craft.

If the health authorities would ordain that as part of the plumbing installation of every house, using water as a conveyor for sewage, a properly designed "septic tank," the measure of the actual sewage would be the amount of the water supply, the effluent would be without odor or sludge and would contain but from 50 to 60 per cent. of the original organic decomposing matter, at once reducing the size of the sewers, the cost of maintenance and simplifying the final purification.

VENTILATION.

Ventilation not only includes the art of getting rid of the waste air but also of providing an ample supply of *pure* air at the proper temperature.

The vicious practice of attempting to provide in the air for ventilation, that heat required to supply the losses of radiation from the walls, etc., should be absolutely abandoned and the problems of heating and ventilation considered independently.

But little attempt is made to accomplish a satisfactory posi-

tive ventilation in our Community Buildings, one of the systems adopted is to install exhaust fans in the attic and provide exhaust flues to and registers in the offices with an ample supply of fresh air from the corridors.

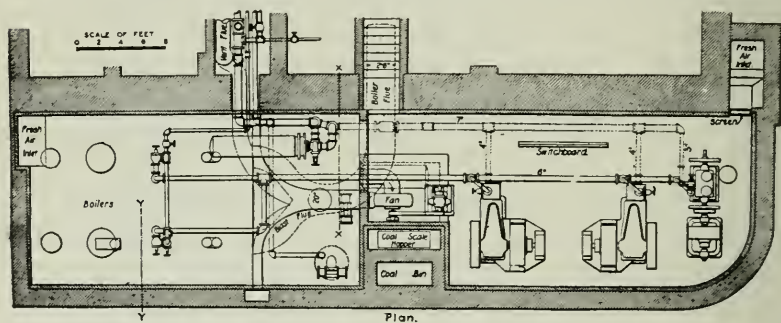
The toilet-room ventilations must be segregated and the air exhausted from the toilet-room hoppers.

In another method, the rooms are heated with fresh hot air and the foul air exhausted.

Most of the recent buildings are content with an omnibus ventilation, from the toilet rooms only.

Any one who has experienced the results can testify to the more healthy and comfortable condition of the well-ventilated building.

As hereinbefore noted, particular attention is again called



Engine and Boiler Room at Art Club, Philadelphia

to the intelligent treatment of the engine and boiler rooms, and at the same time let it be remembered, that even if the municipal laws do not forbid, there is no reason whatsoever that *sci-rocco* from these torture chambers should be insolently blown on and into those who pass by on the street. The air to ventilate and cool the engine room and to supply air for combustion at the Drexel Building, the Art Club, the U. G. I. Building, and at the Gymnasium, University of Pennsylvania, is drawn from the outside, either by the chimney draft or by fans, and by automatic regulation either passed through the furnaces or directly to the smoke flue, as the steam pressure may require. That this is not difficult is proved at the Art Club, where the smoke flue of necessity took a tortuous path involving 900 degrees of arc.

Even in many of our hospitals and asylums no attempt is made to obtain a pure atmosphere.

In some instances the heating and ventilation are treated together with disastrous results, and in the majority in which the engineer and architect have installed well-designed plants, the management decline to use them.

In hospitals for contagious diseases, each ward should be an *individual, receiving all its air from a pure source* and the foul exhausted air passed through a fire before being discharged to the atmosphere.

This can readily be accomplished by using the fans which exhaust the air, as the blowers to supply air for combustion in the furnaces of the steam boilers used for power and heating.

HEATING.

In all properly designed plants the heating should be by the utilization of the exhaust steam from the prime movers.

The heating in the Drexel Building was with exhaust steam from the engines, supplemented by live steam, as is now the general practice. The distribution was downward two-pipe gravity scheme.

The maximum pressure at the initial one-pound above the atmosphere and the minimum one pound or two inches below.

No air valves were used on the radiators, and automatic check supplanted the ordinary hand valve in the return circulation.

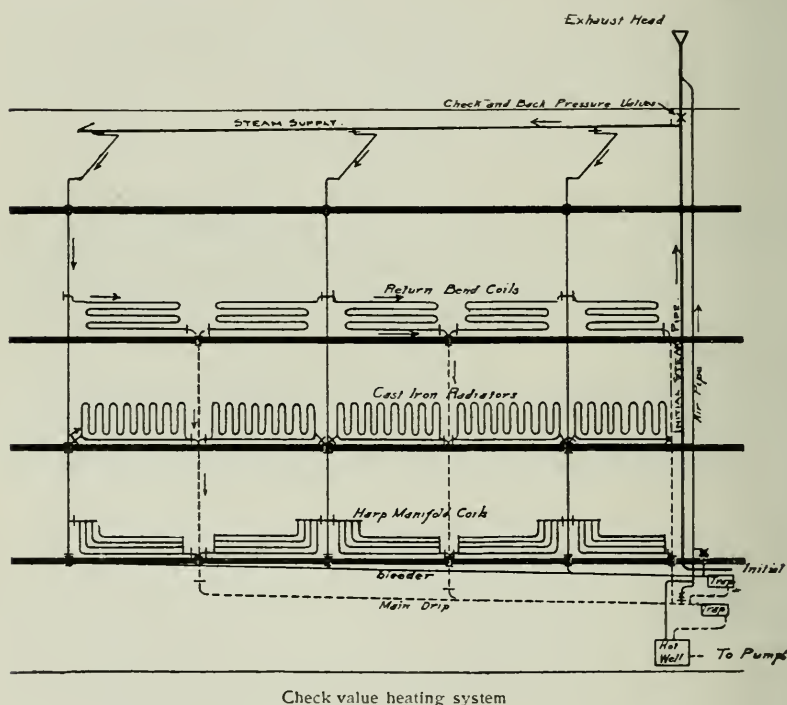
The condensation and air from the radiators and return pipes were conducted into a pipe discharging to a low pressure steam trap. This pipe was also connected with the bleeders from the vertical supply pipes, also controlled by a trap. These connections, before connecting with the traps, were provided with outlets controlled by lock check valves, opening to the atmosphere.

In starting the system and when necessary, the initial pressure is raised above the atmosphere, when, the air in the system being heavier than the vapor of steam, follows the water of condensation, is separated and escapes to the atmosphere through the check in front of the trap.

The Drexel Building has a total cube of approximately 3,000,000 cubic feet, and is ten stories high, and has about

150,000 square feet of rentable floor space, or as much as the Real Estate Building, Philadelphia, or the Empire Building, New York City. It has nearly three times the rentable floor space of the old Land Title Building (Broad and Chestnut) or as there is in the Stephen Girard Building. The circulation of steam was accomplished and the radiators heated in about forty-five minutes.

Contemporaneously and subsequently, this system was used by the speaker in the Trust Company of North America, the



Reading Terminal Buildings, in the various buildings then erected connected with the University of Pennsylvania, and in other buildings also, and was adopted subsequently by other engineers.

In the Drexel Building the system worked well for four or five years, but as the moulding sand loosened from the inside of the cast iron radiators and collected in the checks, it prevented closing, and the water in the drip pipes was sucked

back into the radiator when the supply valve was closed, by the vacuum produced by the steam condensation.

In using the check valve, water is backed up into the radiator until there is sufficient weight to open the check, so that they should be placed, especially on pipe coils, at a lower level than the radiator.

This gives historically, the first or at least one of the first successful attempts to operate a radiator with the supply valve only—and at or below the atmospheric pressure.

Some time between 1886 and 1888, Alex. de Beaumont, an Alsatian by birth, but resident of Philadelphia, conceived the idea of exhausting the air and condensation from the heating system with a vacuum pump, of at once reducing the dimensions of the supply and drip pipes and valves and dispensing with the troublesome air valve, at the same time reducing the initial steam pressure from five pounds, the then prevalent use, to atmosphere and below.

Unfortunately, he confided this idea to an exploiter, who, I am informed, took it bodily, and patented a crude system called by him the "*Williams Vacuum Heating System*." Mr. de Beaumont was thus deprived of the well deserved reward of his ingenuity.

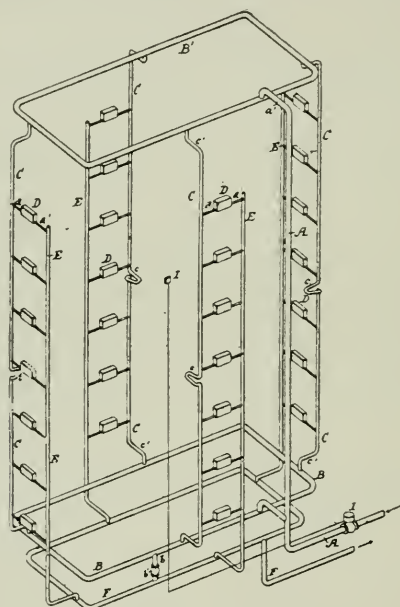
The difficulty in the "Williams" system was this. There being no automatic valve on the radiator drips, short circuits exhausted the nearby radiators and pumped valuable uncondensed vapor to waste, leaving the remote radiators without drainage.

"Williams" sold his patents to "Mr. Warren Webster," under whose guidance the present well-known "Webster Vacuum Heating System" has been put into practical service, fully realizing the hopes of M. Beaumont.

The first plant installed by "Warren Webster" was in 1895-6. The system had merit, and subsequently a large number of plants have been installed. The system, however, at first gave much trouble, and the author was among those who shared in the bitter condemnation for installing this new-fangled scheme. One experience, at the Professional Building, was sufficient to convince the author that to make the system a success, and to take advantage of its merits, we must have clean pipes and radiators, free from the old trouble with the check valve system "moulding sand."

Subsequent specifications by the author required that the radiators must be thoroughly pickled, and absolutely clean before erection; with careful steam fitting the troubles were then over. An example of the latest improvement in steam heating, devised in 1897, may be found in the U. G. I. Office Building, and with your permission I will quote from a paper written by the author and read before the American Society of Civil Engineers in October, 1901.

*⁴⁴Modern practice dispenses with the air-valve and the hand-operated drip-valve, and reduces the size of the pipes by producing a partial vacuum



Double supply heating system

in the drainage system and in the radiators when not in use, so that a flow of steam to the radiators can be maintained below the atmospheric pressure. In the "Webster System" a thermostatic valve takes the place of the hand-operated drip-valve and the air-valve.

"An equal distribution of steam at low pressure, through small pipes, can be readily accomplished by supplying the risers from both basement and attic.

The writer has installed such a system, combined with the "Webster Vacuum System," in the Office Building of the United Gas Improvement Company, a twelve-story building, in which each of the steam supply risers was only $1\frac{1}{2}$ in. in diameter, and served 1600 square feet of radiation. The

steam supply to two radiators, serving fifty-four square feet of surface, did not exceed $\frac{3}{4}$ in. and the drips from the individual radiators $\frac{1}{2}$ in.

"The amount of steam supplied to the entire heating and ventilating systems serving an equivalent of 20,000 square feet of direct radiator surface, was controlled by a pressure-regulating valve. The temperature of the steam in the radiators under test was regulated to vary from 190 to 260 degrees. *The maximum difference in temperature between the initial steam in the boiler room and the farthest radiator did not exceed three degrees when the outside temperature was seven degrees Fhr. and the maximum difference was one and a-half degrees when the outside temperature was thirty-one degrees.*

"The pipe sizes in this system were about one-half the areas previously adopted in vacuum systems and one-fourth the areas in gravity systems as laid out by the usual method of supplying the risers from either top or bottom.

"Using this method of distribution with the "Webster System," a twenty-four-story building could be served with steam supply risers not over two inches in diameter, and serving from 1200 to 1300 square feet of radiating surface, with a better steam distribution than can be obtained by larger pipes and serving only from one end.

"The double supply system decreases the difficulty in concealing the pipes, decreases the cost of construction in tall buildings, and puts the entire installation under more complete control.

"In one-pipe system a single riser is used both to supply and drain the radiators. The risers are supplied at the top, and drain at the bottom, or may be supplied from both top and bottom. With tight valves and reliable air-valves this system, when aided by positive air exhaust, is fairly satisfactory; but the steam supplied to the radiators is wet, the risers are large, and it is difficult to conceal the pipes and provide for exhaust.

"To obtain good results, and prevent short circuits, with the "Webster System," it may be advisable to run independent drip-mains from certain portions of the system directly to the pumps, and not connect the entire drainage system into one main.

"With the Vacuum System and an equal distribution, the heating system becomes an efficient surface condenser, and, excepting in cases of very severe weather, when a steam pressure above the atmosphere may be required, prevents all back pressure on the engines, and generally produces a slight vacuum.

"The vacuum pump required to remove air and condensation from the radiators requires only a trifling expenditure of power. The author found that the power required to operate an electrically-driven pump on the Vacuum System serving 20,000 square feet of radiating surface, did not exceed two and one-half H. P."

Another advantage of the vacuum system is that there is no danger from leakage, and concealed pipes can be used with safety as the system is generally operated at or under the atmospheric pressure, and if there is leakage, the tendency is

for air to leak into the pipes, rather than for water and steam to escape from them.

The Office Building of the United Gas Improvement Company has twelve stories and an attic above the basement and contains, within the exterior limits, a cube of approximately 1,500,000 feet.

There are in all 650 windows and a large skylight, 16,000 square feet of glass or about 25% of the exterior exposure.

The entire building is ventilated by exhaust fans.

The ventilation of the toilet-rooms being segregated and served by a special fan, exhausting the air from the rooms through the toilet hoppers.

The first story is provided with a supply of filtered and tempered air, and also with an exhaust fan system.

The building above the first floor is ventilated with exhaust fans through ducts and registers, and supplied with fresh tempered air from the corridors. The entire building is heated by direct radiators.

The tempered air is warmed with about 3,500 square feet of semi-direct and indirect radiator coils, etc.

About 13,000 square feet of direct radiators are used to heat the rooms, making a total equivalent to nearly 20,000 square feet of direct radiation.

As all the power for the elevators, for electric lighting, for fans, pumps, etc., etc., is generated by gas engines, and the heating is entirely independent of the power, an excellent opportunity was presented to obtain exact data as to the heating requirements.

The heating diagrams were made from records taken at this building from December 18th to December 26th, 1901, and show:

- 1st. The temperature in degrees Fahr. of the outside air.
- 2nd. The wind velocity in miles per hour.
- 3rd. The approximate boiler H. P. required.
- 4th. The pressure referred to atmosphere in the steam and return pipes.
- 5th. The average coal burned per hour, plotted in six hour periods.

From these data it was found that 185 H. P. would be re-

quired to heat the building at zero Fahr.; there had been provided boilers in duplicate of 200 H. P. each.

The largest steam riser is but one and one-half inches diameter—twelve-stories high, 170 feet long, and serving 600 square feet of radiator surface.

OFFICE BUILDING OF THE UNITED GAS IMPROVEMENT CO., PHILADELPHIA, PA.
HEATING DIAGRAM - DEC. 15th TO DEC. 22d, 1901.

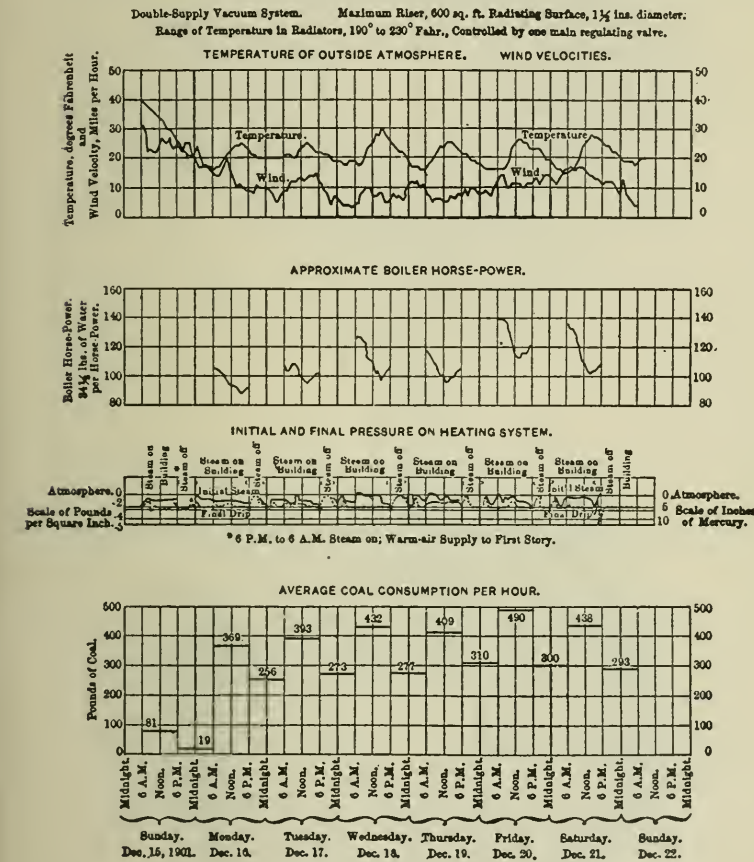


FIG. 3.

By the operation of one automatic valve in the initial steam supply mains a range from 190° to over 230° Fahr. has been obtained to suit the varying conditions of the outside weather. This flexibility can be increased to a range of at least 60° Fahr. so that the radiating surface may be figured for the average

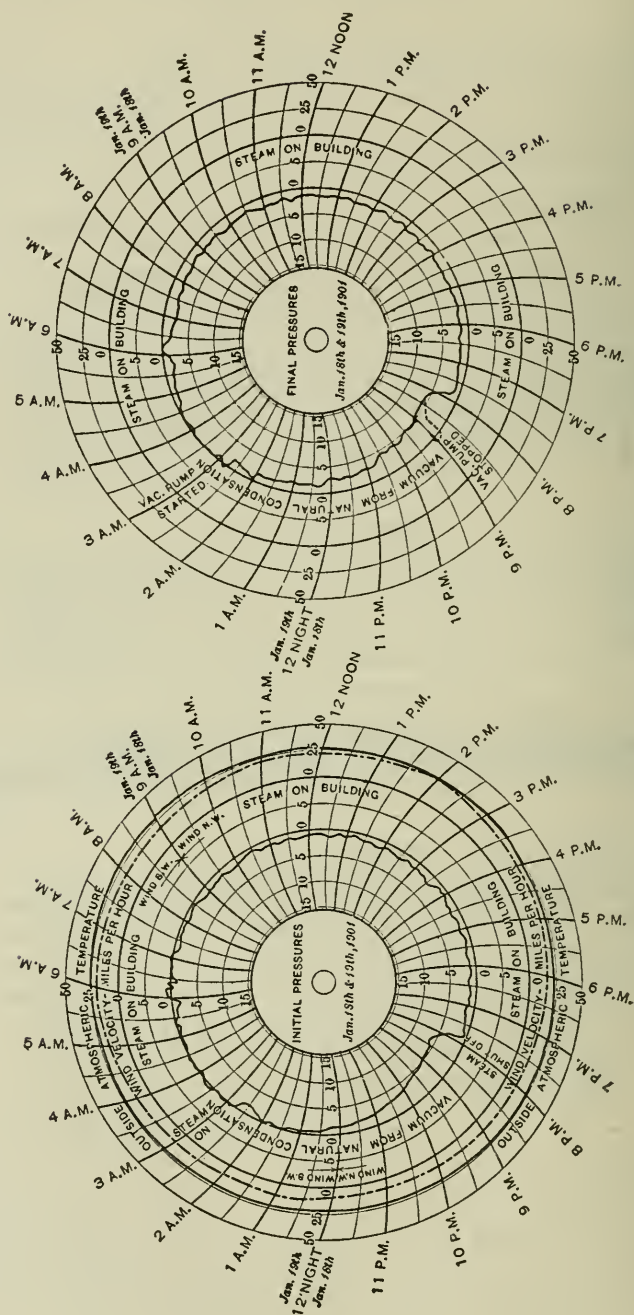
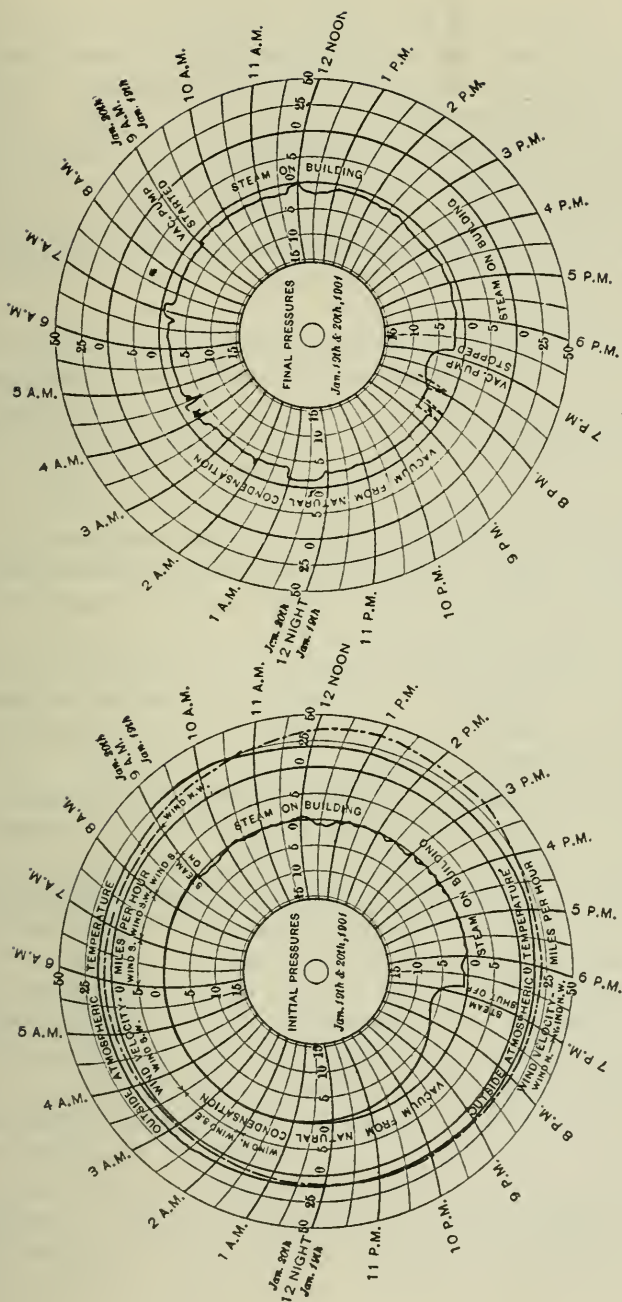


Diagram. January 18, 9 a. m. to January 19, 9 a. m.

Diagram — January 19, 9 a. m. to January 20, 9 a. m.



winter weather, say 30° Fahr., and when the incidental very cold snaps obtain the steam pressure in the system, and consequently the steam temperature, can be increased—saving both in first cost and operation.

To further illustrate the operation of the double supply distribution, obtained with the Webster Vacuum system, the author submits the appended diagrams, showing the pressures on the steam supply radiators and drip pipes from Friday, January 18, 1901, at 9 A. M., to Sunday, January 20, at the same hour.

On the diagrams showing the steam pressures in the supply pipes the hourly outside temperature and wind velocities have been plotted, and show how the wind velocities reduced as the outside temperature lowered. The temperature in the building was maintained at 70° during office hours, which lowered slightly during the night, after steam was shut off.

On January 18th the initial steam pressure on the supply pipes varied from 1 to 2 lbs. below the atmosphere from 9 A. M. until 7.45 P. M., when all the steam was shut off and the vacuum pump stopped.

The pressure then reduced by condensation to 6 lbs. below the atmosphere. Leakage of air into the system produced an equilibrium at 3.00 A. M., January 19th, when the pump was started.

Steam was then turned into heating system, and atmospheric pressure was maintained until 7 A. M., when it was reduced to 1 lb. below the atmosphere until 9.45 A. M., and varied from 1 lb. below to atmospheric pressure until 6.45 P. M., when steam was shut off, and the *pressure reduced by condensation to $6\frac{1}{2}$ lbs. below the atmosphere.*

Leakage did not fill the system with air until after midnight. The vacuum on the drainage system produced by the pumps varied from 1 to $2\frac{1}{2}$ lbs. below the atmosphere, and the difference between the initial and final from $\frac{1}{2}$ to 1 lb.

In the heating system from which these diagrams were taken, the steam risers were $1\frac{1}{2}$ inches in diameter, and 170 feet long; each served about 600 square feet of radiation.

The initial steam pressure on the system may readily be raised from 2 to at least 10 lbs. above the atmosphere during

the most severe conditions, producing a correspondingly higher temperature in the radiators.

To illustrate the comparative dimensions of the supply and drip pipes as used by the different systems, a diagram is exhibited. Curve No. 3 shows the diameter of the risers for the corresponding radiator surface, if they are provided with a double supply, and the system is drained by gravity, or by the Webster Vacuum System, supplied either from top or bottom.

Curve No. 4 shows the diameters of the pipes in the Webster Vacuum System supplied from both ends.

The writer has found that the size of the drip pipes noted in Curve No. 6 is sufficient for the risers on the gravity two-pipe system.

In tall buildings it is not considered good practice to make the least dimension of the riser less than 3 inches diameter, increasing toward the source of the supply; say, in a 24-story building, the riser serving 1,200 feet of radiation, the largest diameter of pipe on a one-pipe system would be not less than $3\frac{1}{2}$ inches, and with a double supply vacuum system the diameter would be less than 2 inches.

In serving the risers from both top and bottom, the building is practically divided into two buildings, one served from above, the other from below, with the advantage of equating the variable steam demands from either the upper or lower supply.

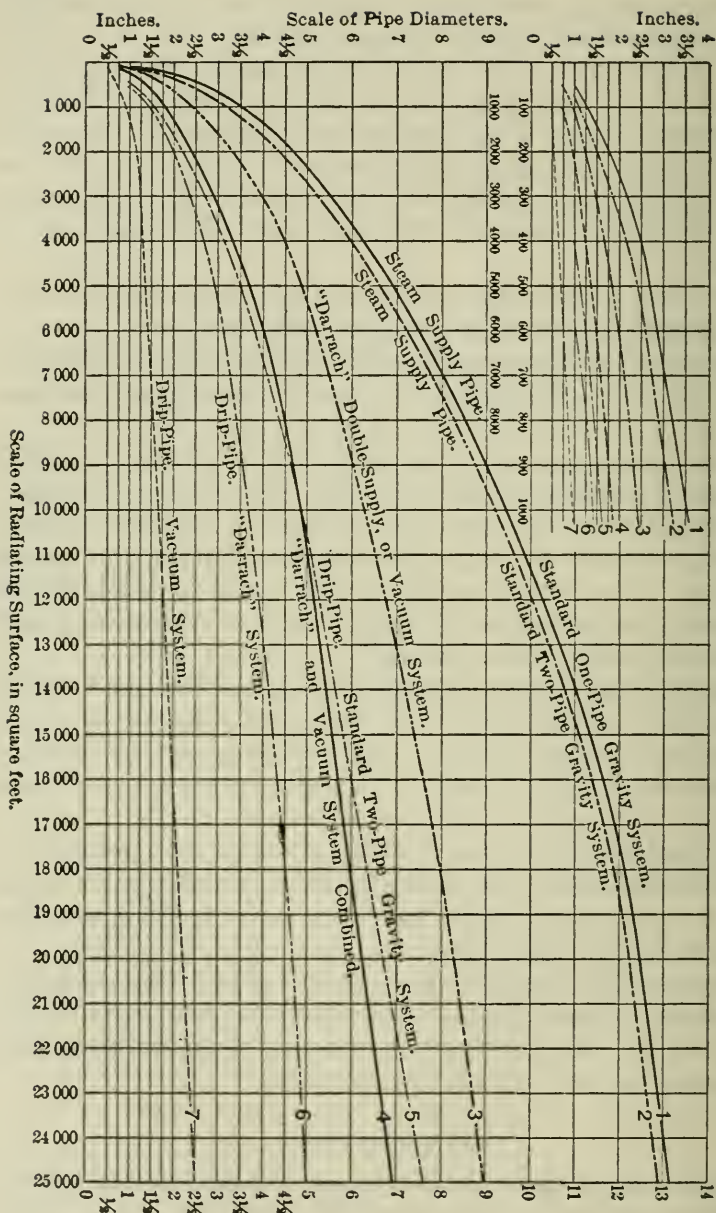
The double-supply system has the advantage of giving more equable distribution, and, as the pipes are smaller, there is less trouble in concealing them than if the entire building was supplied either from top or bottom.

The one-pipe gravity system, supplied either from the top or the bottom, requires pipes of maximum size, and in tall buildings they are often difficult to conceal, without taking into consideration the question of expansion.

REFRIGERATION.

In some of the later office buildings, I think the first in Philadelphia, being the "Fidelity Life Insurance" building, a system of refrigerated water was installed, serving individual offices for potable purposes.

COMPARATIVE DIAGRAM OF STEAM HEATING AND DRIP-PIPES.



This is accomplished by the well-known ammonia process. Cool air is also supplied to a limited number of large offices, theatres, etc.

In the Land Title building this is accomplished by passing the air through a veil of falling water. In 1902 the author recommended, for the installation at the Gymnasium of the U. of P., substituting in the summer cool water for steam in the coils used to temper the air used for ventilation.

The transition from steam to gas as a prime mover has been described, as well as the use of electricity as a conveyor, which system, however, does not produce a usable by-product.

He is of the opinion that a better and cheaper sub-agent can be utilized.

When compressed air is used in an expansive engine the exhaust is reduced to a low temperature, depending upon the initial compression.

Thus, in giving a vehicle for *power and cold*, and we obtain, all that can be desired in addition to our old friend steam, which is the vehicle for *power and heat*.

During the winter the exhaust steam is used to heat the building and the water, etc.

During the summer the exhaust air may be used to cool the building, the water, etc., by means of the same apparatus installed for heating.

The double-supply system of distribution herein before described for steam heating is most *apropos*.

If we install in the basement only the boilers, the steam engines and air compressors and house pumps, all the other apparatus may be located in the attic.

WATER PURIFICATION.

There was installed in the Drexel Building (1887) a duplicate system of rapid sand filters, designed by M. Henry Roeske, so arranged that the sand could be sterilized with high pressure steam.

These filters were supplemented with ample storage for filtered water in the attic.

They have never been taxed, although the population in the building has been doubled, and now, after nearly twenty years

of service they are still jogging along in a comfortable and vigorous old age.

This was the state of the art and of the so-called "American system of mechanical filtration" in 1887.

Since that time many excellent forms of filters suitable for isolated plants have been put on the market, among others "The Loomis-Manning Filter," "The American Filter Co.'s" apparatus and the "Roberts" filter.

All these filters differ principally in the mechanical methods utilized in cleaning the filtering material, be it sand, animal charcoal or both; the coagulation of the organic impurities usually being induced with alum.

The utilization of the electric current for coagulation and for the aeration of the water, although first proposed before 1880, has not as yet reached much further than the experimental stage.

In his experiments the author has successfully removed all trace of stain by aniline dye, and is convinced that not only clarification, but in high degree of purity can be attained by a combination of chemical, electrical and mechanical methods, which will not be beyond the reach, either in first cost, or in expenses of operation, of all community buildings, be they office, hotel, hospital or factory.

OPERATION.

I have already tried your patience beyond the limit, but if you will permit I will speak a few words in relation to the economy of operation of the plant.

The most important is to reduce the expense of the combustible to a minimum; we should, therefore, use a minimum amount of the best quality at the lowest price.

To accomplish this result, every plant should be provided with a weighing apparatus, not only to weigh or measure all the combustible that is delivered to the building in bulk, but also all burned by each shift. The resulting ashes should also be weighed and records kept.

Contracts for combustible should be based to a standard and periodic tests made to enforce the stipulated provisions.

The boilers should be of such capacity as to be operated at the rate of maximum economy with ample reserve.

If you have a limited boiler capacity, urge your principals, in season and out of season, to enlarge it; remembering that then you can burn at minimum cost the rice sizes.

Also, in addition to anthracite, be prepared to burn any combustible—gas, alcohol or bituminous coal—for which cheap apparatus can be installed for any boiler and any setting, without in any way interfering with either the usual operation or with the smoke ordinances.

Great care should be taken that all the exhaust steam possible is utilized, and that no leaks of steam and hot water are permitted.

In this connection your particular attention is called to that insignificant but necessary steam trap—probably, when neglected, the most wasteful apparatus in the installation, located, as it generally is, both out of sight and out of mind, it wastes while you sleep. Install as few and as conspicuous as possible, and give them your individual care. Boilers and engines should be as economical of steam consumption as the invested interests will warrant, and kept in prime condition.

To this end, the operating engineer should be able to use and (in addition to the ordinary scales and the gauges required by law) be provided with indicating and recording gauges for steam, electricity and water, as well as with thermometers, manometers and indicating apparatus.

You may then only expect a minimum expense for fuel.

The next item is in the cost of lubricants. There is no doubt that many of the oil bills can be reduced to much less than half, with more intelligent care and less labor.

Improvements in apparatus for substituting lubricating grease for oil will, in the near future, reduce both the labor and the lubricant to a minimum.

Particularly urge your principals to abandon all automatic flushing apparatus in your sanitary plumbing. The chain pull or the flushometer is better, more certain and you don't have to pump so much water, even if the municipal authorities don't care how much is wasted.

CONCLUSION.

In conclusion, I would urge the intelligent, earnest, self-abnegating and courteous co-operation among the many inter-

ests and individuals to whom is intrusted the production, operation and maintenance, of that marvel of our present civilization, THE COMMUNITY BUILDING.

Philadelphia now has a world-wide reputation for loss of civic pride. Why is she called provincial? Why must she scour the wilds of some Terra del Fuego for talent to design, to construct or to manage her affairs?

Notwithstanding, it can be said, without contradiction, that the most novel scientific inventions and the most important discoveries that have benefitted mankind have been the productions of her own born citizens, fostered by the *Alma Mater* of Western Science—this institution, of world-wide fame—

THE FRANKLIN INSTITUTE.

DISCUSSION.

MR. CHAS. A. HEXAMER:—The interest of the fire insurance engineer in modern office buildings is mainly in the construction, interior fire protection, protection against fire in adjacent buildings, and housekeeping, that is to say, in the general condition of the building as to cleanliness, disposal of waste paper and rubbish. The question of construction, heating, lighting and ventilation has been clearly set forth by Mr. Darrach. As to interior protection, the insurance engineer generally recommends a standpipe supplied by an elevated tank and a fire pump, hose outlet on standpipe not less than two inches. Three gallon chemical extinguishers are required, and a forty gallon chemical extinguisher on wheels, located on each floor, is recommended. As an example of standpipe and hose system, attention is called to the arrangement in the Land Title Building, Broad and Sansom Sts. Their being no fire pump available, a 3,500 gallon pressure tank was located in the twenty-first story. This tank primarily supplied the standpipe, but as the amount of water available is small, a three and one-half inch screw connection to standpipe was provided outside of building line for the purpose of making connection by means of a hose line with the hydrant of the high pressure fire system. By this simple arrangement an efficient water supply

to the standpipe was secured for any emergency and for every story of this extra high building. The pressure tank referred to, is also connected with the sprinkler system installed for the protection of the waste paper room in the top floor, which room has been reduced to a minimum size by enclosing same with fire resisting partition. It is interesting to note that an actual fire in this room was extinguished by a single sprinkler opened by the heat of the fire.

The protection of office buildings against a possible fire in an adjacent building needs careful consideration. Wire glass windows or outside open sprinklers over the windows, if the exposure is moderate, or standard fire shutters, are recommended. As an example: In the case of the Girard Trust Building at the N. E. corner of Broad and Chestnut Sts., the the windows in the east wall exposed by the Mint Arcade have been protected by steel shutters and in addition a system of open sprinklers over each shutter has been installed. This system of open sprinklers is supplied by a steam fire pump located in the basement of the building, and in addition a three and one-half inch screw connection has been provided on the Chestnut Street front of the building, so that by means of a hose line and the hydrant on Broad Street the high pressure pipe line could be made available to supply the open sprinklers.

As to house-keeping: It is essential that the waste paper accumulating in the offices be regularly removed and not allowed to accumulate in the building. A waste paper room, of a minimum size, and enclosed by fire resisting partitions located preferably in the basement, is recommended. The waste paper room should by all means be protected by automatic sprinklers. Rags used for cleaning purposes, particularly if oil is used to rub down and polish furniture, should be carefully disposed of, and not, as was done in my own office, placed in a cupboard in immediate contact with the hot steam pipes. It should always be remembered that while a modern office building may be of fire resisting construction, as a general thing there is sufficient combustible material in any one room to cause serious damage should fire occur. How seriously a so-called fireproof office building can be damaged in a conflagration, was demonstrated at the time of the Baltimore fire.

MR. JAMES CHRISTIE:—When the so-called direct system of heating is employed, the ventilation is unsatisfactory. The indirect system, by filling the rooms with a sufficient supply of pre-heated air, is best from the hygienic point of view, but, unfortunately, the cost of heating is usually greater by the latter method. Frequently good results can be obtained from a combination of the two systems, the corridors, etc., being filled with pure air at a moderate temperature, and apartments brought to the desired higher temperature by direct radiation.

When a supply of cool, dry air can be economically obtained, the same indirect system used for winter heating can be applied to cooling in summer.

This has been done to some extent in connection with a refrigerating system, and permits of windows being kept closed in summer, thus excluding a dusty or smoky atmosphere, a most desirable object in some locations. At the new works of the American Bridge Company, at Ambridge, Pa., there is an ample supply of cold water, running 55 to 60° Fahr. in the hottest months.

The water supply of the office, in the summer months, can be passed through the same coils in which steam is used for heating in winter, the same fans that push warmed air in winter discharged cooled air in the hot months, thus, in addition to well-aired offices, it is practicable to reduce the temperature from 5 to 10° below that otherwise existent.

DEPOSITING COPPER ON ALUMINUM.

Copper has been successfully deposited upon aluminum by the use of an anode of pure copper and an electrolyte of water, with a few drops of sulphuric acid in it. After the current had been in action for some time copper sulphate was formed, and from this the copper was deposited. After thirty minutes the plate was taken out and well washed in water, then in a solution of hydrochloric acid, then in sodium hydroxide, and again in water. This operation was repeated several times, the final result being an even deposition of copper all over the plate. Further experiments included the deposit of antimony upon the coppered aluminum plate. Lumps of trisulphide of antimony were placed in a porous pot with a carbon anode, and the cell filled with the electrolyte, which in this case was a concentrated solution of sodium sulphite. On the coppered aluminum cathode the antimony adheres firmly, the current density being 0.0013 amperes per square inch, with a pressure of from 1 to 1.5 volts.

—*Iron Age.*

CARBONIC ACID AS A CAUSE OF RUST.

In view of the important place given to preservative coatings in the programmes of engineering associations and the divergent views on the cause and prevention of rust, interest attaches to the data presented by Gerald Moody of the Central Technical College, at a recent meeting of the Chemical Society in London. The accepted theory has been that the presence of oxygen and moisture would always cause rust, and the view of some chemists that carbonic acid played an important part in the reaction has been considered disproved by experiments carried on by Dunstan, Jowett and Goulding.

Mr. Moody, as reported by the London *Engineer*, held that minute traces of carbonic acid are sufficient to set up atmospheric corrosion, and he entered upon a series of experiments to justify his opinion. In these experiments extraordinary precautions were taken to exclude the minutest traces of carbonic acid. His plan was to keep a sample of highly polished iron in a few drops of distilled water for prolonged periods and to draw over it a continuous stream of air freed from carbonic acid by passage over caustic potash and soda lime. In some instances three weeks were expended in purging the apparatus of carbonic acid alone before the water was allowed to reach the iron, and for six weeks the pure air passed over the sample. At the end of this time the iron was as bright as when the experiment began. But, on the other hand, when air containing the normal quantity of carbonic acid was drawn over the sample, in six hours the bright surface was tarnished, and in seventy-two hours, during which time about sixteen litres of air passed over it, "the whole surface of the metal was corroded and a considerable quantity of red rust collected." The question presented by these experiments to the manufacturer of preservative coatings is how to exclude or neutralize the action of the carbonic acid carried by the atmosphere or by moisture.

Two correspondents of the *Engineer* comment on the above to the effect that there must be moisture to cause rust. One says that the experiment of the late Prof. Crace Calvert, in 1869 to 1871, showed that with dry carbonic acid there was no oxidation, and that the most rapid corrosion took place when the iron was exposed to damp "oxygen and carbonic acid." The other correspondent says that in all cases of rust water as well as carbonic acid and oxygen must be present; that no oxidation can take place without water, though it has not been ascertained how much moisture must be present or the precise part it plays.

HEATING VALUE OF COAL AND CRUDE OIL.

Tests have been made in California to determine the relative heating value of crude oil and local coal. One net ton of coal was found to be equal to 718 pounds of oil. As this oil weighs 7.6 pounds per gallon, and one barrel holds 42 gallons, the above quantity is expressed as $2\frac{1}{4}$ barrels. For locomotive purposes, where a better grade of coal is used, the requirement of oil to equal 2000 pounds of coal is 1037 pounds, or $3\frac{1}{4}$ barrels.

ONE LESSON OF THE EARTHQUAKE.

If argument were needed to show the advisability of an investigation of structural materials it is more than supplied by the recent earthquake in California.

What buildings best stood the shock is a question of very great practical interest. Why they endured while others fell is food for thought to builders all over the country.

In this connection it is interesting to note that the Appraisers Building in San Francisco, where the United States Geological Survey maintains a local office, is one of the few business structures in that city which was uninjured either by shock or by flame. Mr. Charles G. Yale, special agent of the Survey, reports that a little plaster has fallen but that the building is probably the only one in the city that shows not a single crack in its brick walls. This may be due to the fact that the foundation consists of a six-foot bed of solid cement placed upon thousands of piles, and that the bricks are put together with cement instead of mortar. The walls are thicker below the sidewalks than above them. When the building moves, it moves as a monolith, and while the vibration is considerable, no damage has been done except to the plaster.

That the Geological Survey might with profit to the country undertake the investigation of structural materials is attested by the numerous requests which it receives for information on the subject. Twice during the past year the Survey was visited by a body of engineers who represented large industrial developments in a number of different States. The Survey was unable to supply the information which they desired concerning the strength and endurance of materials to be used in a variety of building and construction work. This one fact shows how desirable it is that the investigations now under way by the Survey be enlarged.

These investigations have thus far had to do mainly with the testing of cements and concretes. It is felt that the work should be continued and amplified.

LARGEST PAPER-MAKING MACHINE.

Some idea of the dimensions of the largest paper-making machine ever constructed in the United Kingdom may be had from the fact that it fills a shed 185 feet long. It has great width, due to the fact that the Swedish Paper Mill Company, for whom it was built, intends to use it for the production of two 75-inch sheets of paper, a total width of 150 inches, or 12½ feet. The paper is to be run through the machine at the high speed of 500 feet per minute, which calls for very heavy and accurate driving gear and large rolls. To provide paper of a superior finish a stack of calendar rolls is fitted, weighing seventy tons, the lowest one alone accounting for nearly fifteen tons. The entire machine weighs 550 tons, and is driven by a 200 horse-power steam engine. The machine was built in Edinburgh, and conveyed to Sweden in a special steamer chartered for the purpose.

CHILEAN NITRATE DEPOSITS.

According to recent publications by Semper and Michels (Berlin, Ernst, 1904), the various theories hitherto proposed to explain the formation of the Chilean saltpeter deposits (microbes, varech, guanos, etc.) must give way to those formulated by the *saliteros*, or Chilean miners, who ascribe the formation of saltpeter to atmospheric electricity. There is a remarkable amount of mist surcharged with electricity in the Pampas, where the saltpeter is mined, so much so that telephones are deranged. Apparently the oxonized air disengages nitrate of ammonia, which combines with rock salt to form saltpeter. But as the region is rich in guanos and other organic deposits, says the *Mining Journal*, there might be reason to blend this theory with that of Ochsenius.—*Eng. and Min. Jour.*

BEHAVIOR OF INCANDESCENT MANTLES.

In using incandescent mantles for gas lighting it is usually found that illumination increases for a short period, after which a slow but steady fall sets in. The initial rise is credited to a gradual shaping of the mantle to the flame. The subsequent fall is attributed to two causes. One is that dust particles of silica are carried by the draft against the mantle, where they form, with the oxides, infusible silicates of low emissive power. The other, and more potent cause, is the gradual volatilization of the ceria, to which the incandescence is due. It is also found that the hygroscopic state of the atmosphere has a small but measurable influence on the luminosity of the mantle.—*Iron Age.*

MEASURING FLOW OF AN ARTESIAN WELL.

Under conditions where a weir could not be built, a novel way of measuring the flow of an artesian well was devised. Forty feet of ten-inch pipe was screwed into a ninety-degree elbow on the pipe where it came out of the ground, and a hand force pump attached to a small hole tapped into this pipe. The force pump drew a red aniline liquid from a pail and injected it into the stream, where it was carried along with the water and at the same rate. By means of a stop watch and the known carrying capacity of the pipe the flow of the well was easily determined.—*Iron Age.*

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THE FRANKLIN INSTITUTE

The Democrazation of Industry, or Enlightened Methods of Treating the Employed.*

BY H. F. J. PORTER, M.E., New York City.

I am going to talk to you to-night on what I call "Enlightened Methods of Treating the Employed." I say "enlightened" methods to distinguish them from those which belong distinctively to the past and are now being gradually given up as obsolete.

It does not need any proof, in fact, it is a commonplace, to say that this old world of ours is forever changing for the better. There is a force that down through all the ages has continually made for progress, and as in all the different arts and sciences that have brought about our present civilization, there have been development and improvement, so in those which affect the government of nations entering into that civilization there have been, more than in all the rest, changes for the

*A lecture delivered before the Franklin Institute and the Young Men's Christian Association, January 19th, 1906.

better. No people should appreciate this statement more than you as residents of Philadelphia, who have just passed through a change in your municipal government from a bad to a better condition of affairs, and you should understand that government of the many, as in a municipality, does not differ in the principles of the art, from the government of the few, as in a commercial enterprise. In either case, a large group of individuals is formed, to accomplish certain results and this group is governed and directed by a smaller group.



Individual wash basins and wire clothes hockers, lavatory of Weston Electric Instrument Co., Newark, N. J.

The art of government is as old as the human race. In early times the type of government was patriarchal, with the strongest man of the tribe at its head, and this was the prevailing type for centuries, and it was ideal, as long as the tribe was small, for the leader knew each member and all could council together as a family; but as the tribe grew in size these close relations were no longer possible, and the leader was precluded from associating with the many. He then surrounded himself with his favorites as advisors, built up his army, and

his church, assessed the tribe for their support and his permanent authority was established. This was the second stage in the development of government. It assumed the shape of a military organization with generally a tyrant at its head.

Now it is a law of ethics that the abuse of power which almost always accompanies its possession, generally leads to its overthrow, but so strong is habit and so tenacious our hold upon tradition, that successors have always followed in the beaten path with only such restrictions to their authority as their outraged subjects dared to institute. But great evils gradually bring about conditions which ultimately effect a cure. At last the people, restless under tyranny, realized their power and began to exercise it by forming political parties and injecting into the art of government the principles of democracy, a word derived from the two Greek words—*demos*, the people, and *kratein*, to rule. Thus has come about the third and last stage of government, "Of the people, by the people, for the people."

A long, tedious struggle it has been to break the fetters which have chained men to the past, but history shows that the tendency has been towards democracy in all directions. First, religious democracy, giving every man the right to worship God according to his conscience. Second, political democracy, giving every man a right to have a voice in making the laws which govern him; as our Declaration of Independence puts it—"The right of every man to life, liberty, and the pursuit of happiness." And these changes have come about through education, through teaching men and women to think. And now, thirdly, we are witnessing the advent of industrial democracy.

Industrial establishments have until very recently been run on the patriarchal system of government. Until the introduction of machinery they amounted to small aggregations of people all of whom were on terms of intimacy with the owner. The interests of master and men were understood to be closely identified and often led to family ties. Those were days of wholesome toil for both the employer and employee, the former being as skilled in the craft as any of his workers. But the growth of industrial enterprises became phenomenal when the steam engine revolutionized methods of manufacture, and the great numbers of employees which constituted their work-

ing organizations have made the employer a stranger to his help.

Thus the second stage of the development of industrial government arrived, and the man in control being the possessor of power, promptly assumed the role of dictator and oftentimes became a tyrant. The inevitable exercise of undue authority has led to resentment in the industrial field as it had in the others, above mentioned, and the industrial revolution led by those whose interests were common brought about the trades unions, which have for some years been forcing a change to methods which are more democratic. Employers took little heed of history when they ground down their workmen until they organized for mutual protection and then punished them for organizing.

We are all too prone, in the freedom of democracy, to feel that the possession of rights gives us license to do as we choose, or at least as much as we are allowed to do. This tendency has brought about laws for our restraint. The employer can no longer do as he pleases. He must either counsel with his men to find out what they need, or what they want, or he will receive the information by a more indirect though no less positive channel. But there are still moral restrictions which cannot be embodied in the law and these, we are now learning, are equally essential of observance in the growth of a successful democracy.

For instance, by parity of reasoning, if one has the right to vote, has he not a right not to vote, or to sell his vote, or to stay at home and let someone else vote for him? If he has a right to run for office, has he not a right to use that office for private gain, or to do just as he pleases with it? If he enters business, has he not a right to run that business as he chooses? By no means. There has been too much of this kind of reasoning. We must learn, and we are rapidly being forced to the realization, that in every individual right there are duties to others involved. That if one assumes a duty it becomes not only a privilege but an obligation. Inalienable rights mean inalienable duties. The sovereignty is in the people. The latter are becoming educated and in education is salvation.

Of late there has been a moral awakening to our obligations.



Billiard room in Recreation Hall.
Weston Electric Instrument Co., Newark, N. J.

there has been an ethical trend to affairs, religious, political and industrial. We have in our religious circles settlements formed for social betterment, in our political affiliations, we have federations for civic betterment and in the world of commerce we have institutes for industrial betterment.

There are various devices for improving the condition of our shops, and methods of treating employees to carry out the ethical method of management, all of which are recognized as safe of application, provided they are appropriate to existing conditions. The devices referred to found their beginnings in Germany towards the latter part of the last century. They con-



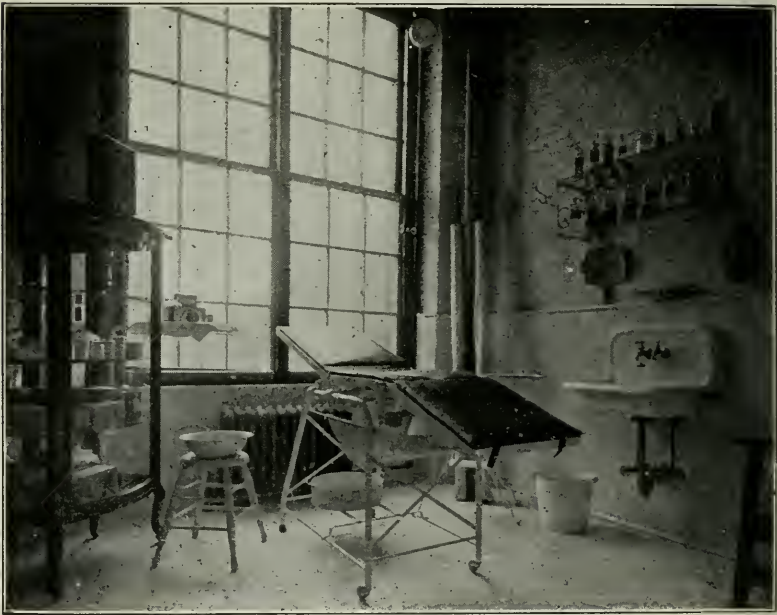
Wash basins and shower baths.
Cleaveland Cliffs Iron Co., Ishpeming, Mich.

sisted in well lighted work rooms—cooled in summer and warmed in winter, bright, cheerful and comfortable lunch rooms where the workers could obtain a wholesome and substantial meal at a nominal cost, emergency hospitals where first aid to the injured could be administered, rest rooms for the temporarily indisposed, reading-rooms where the best literature, both popular and technical, could be obtained, lectures and classes for the instruction of those who desired to improve and advance themselves in the works, organization, clubs, gymnasiums, baths, beneficial organizations, pension systems, etc.



Bulletin board and suggestion box
Nernst Lamp Co., Pittsburg

The fact that these features produced and attracted better workmen and that better product resulted became obvious to enterprising American manufacturers who were traveling abroad in search of new methods for meeting competition, and it was not long before they were tried out under conditions as they existed in factories in this country, and were rapidly adopted, as soon as their paying qualities were demonstrated. These features as they had been introduced originally in Germany under the paternalistic proclivity of the government had received the designation "*Wohlfahrts Einrichtungen*," or Welfare



First aid to the injured. Hospital room
J. H. Williams Co. (Drop forgings) Brooklyn, N. Y.

Institutions. This phrase has been badly translated into English as "welfare work," and gives to those to whom it is applied a feeling that they are objects needing special treatment, which is an unfortunate interpretation of their present purpose. But these features are merely initial steps in the industrial betterment movement referred to.

Good wages and the good will of the employer and of the management must accompany their introduction or they will



District Sales Managers Banquet at Annual Meeting.
Nernst Lamp Co., Pittsburg, Pa.

not accomplish their purpose. In other words, Industrial Betterment will fail utterly unless the spirit of loyalty infuses the whole organization from employer down to the least paid employee. It is the introduction of this spirit that requires the highest intelligence and a thorough understanding of human nature. It is hard to realize the attitude of mind necessary to successfully introduce betterment into a shop where nothing of the kind has ever been considered. All preconceived ideas as to how shops must be organized and managed have to be revised.

Our system of preparation for service has grown so fast that they have never gotten into joint and have not harmonized. We try first in the public schools to educate our people to think, and when they are old enough to work we put them into factories and industrial enterprises of all kinds and then we do not take advantage of the instruction we have paid so much to give them. There they are with their power of thought more or less developed, and we do not make an effort to encourage their originality. On the contrary, we say to them, "do as you are told." "Do as someone else has planned for you," and so we do not reap the harvest that we have spent so much effort in sowing. The principles of the military form of government still persist where implicit obedience is required with no originality of thought.

The implicit obedience theory is wrong, for it does not enlist the will in co-operation, and co-operation is what is necessary for mutual success. Nor is this the only result. Man is by nature a thinking animal. The trouble with most of us is that we do not think independently. As I have said, we are not encouraged to do so. We think as someone else thinks or as we think someone else thinks we ought to think. And so, as the employer makes no effort to direct the thoughts of his employees, it is left for the demagogue or the yellow press to do it and then the employer wonders why his organization thinks differently from the way he wants it to and is so disinterested in his welfare.

But human nature in the employee is the same as in the employer, and when a man feels that his employer cares nothing for him or his interests, he is very apt to return that sentiment, and so the two instead of co-operating in a common interest

become antagonistic, each working for his individual interests only. The workman has come to regard his employer, who he never sees, as an oppressor who is trying to get from him all he can for the least money. The employer feels that his workmen are trying to do the least they can for the wages he gives them. That is the feeling they actually possess, although each knows that their interests are really common.

The mere increase in number, from the single capitalist, who



Library and reading room.
Weston Electric Instrument Co., Newark, N. J.

becomes the partner of a man who supplies skill to develop a project, does not alter the relations which exist when the employer has many employees. The employer and the employed are still partners. The interest of the employees in his enterprise must be secured and maintained if the employer wants their co-operation, and to do this the employer must reciprocate by showing an interest in the welfare of the employees.

Human nature is human nature without any exception. A man will do more for his friend who is doing all he can to



Girls rest room and infirmary
Nernst Lamp Co., Pittsburg, Pa.

help him than he will for one who shows openly he cares nothing for his interests. Employers who sustain relations of the first kind with their workmen testify that without such co-operation they could not have attained their present success. They testify that a minimum of friction exists, that the machine moves smoothly and rapidly and the desire on the part of the worker, to subserve the interest of the employer implies good workmanship, increased production, and therefore, greater surety to the enterprise. In other words, co-operation pays.



Assembly room

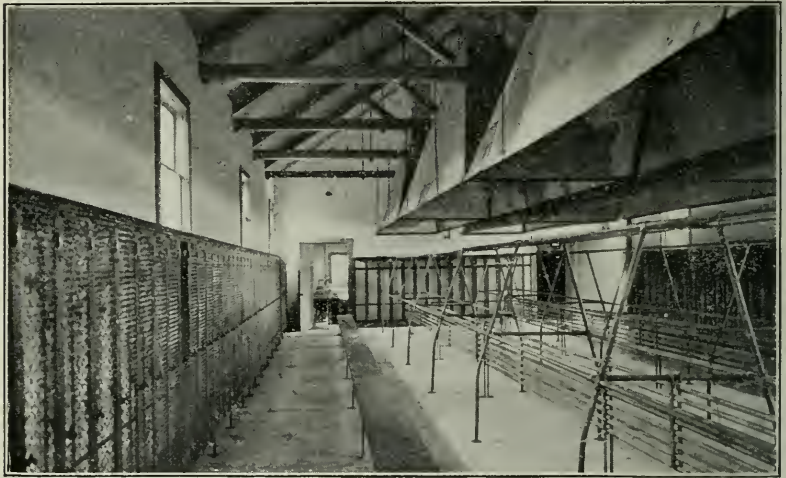
J. H. Williams (Drop forgings) Brooklyn, N. Y.

This is only common sense, we have known it always, but we have waited for the twentieth century to come before practicing it.

Intelligent provision for the best conditions of comfort and best facilities for producing work results in attracting the best grade of workers, who are capable of the best service, a mutual uplift is accomplished, an environment is secured in which the antagonist, the idler, the incompetent, become eliminated by their own initiative. In other words, the more capable the

individual and superior his facilities the better will be the accomplishment. As Walt Whitman said, "Produce great people, the rest will take care of itself."

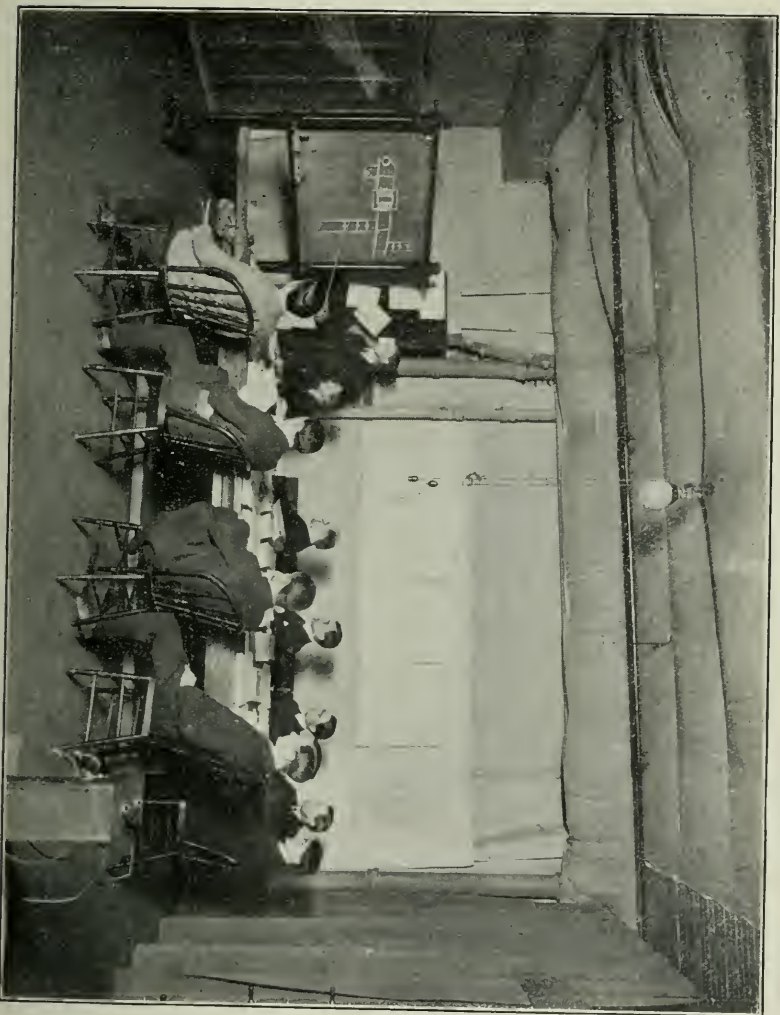
These ideas are not new. They are as old as the human race, and yet they have been practiced rarely and only when employers have realized their civic and moral responsibilities and knew how to meet them. The inertia of selfishness is great. Men wish to keep all they have and grasp for more, and it is usually competition or intensified self-interest which awakens them to adopt means other than they are accustomed to, to protect their interests.



Lockers and clothes drying racks.
Cleveland Cliffs Iron Co., Ishpeming, Mich.

Those employers who have come to see that they are not sufficient unto themselves, but by the assistance of their fellows and through their co-operation have attained success, have opened the eyes of others more conservative to a realization of the fact that if they desire to win the race they must adopt a more enlightened policy of action.

And yet there are many who are still incredulous of what they have been told of the success which follows the application of these common sense principles. They have hesitated to accept the evidence which has been presented to them. Now, to accept theories without practical tests is manifestly unsci-



Salesmen's school in factory. Nernst Lamp Co., Pittsburg, Pa.

entific and dangerous, but to reject the facts when the evidence is plain is equally unscientific and dangerous. Science and wisdom lie respectively in the detection and acceptance of the truth, not in the rejection of it, and it is possible to err by rejecting truth as well as by accepting what is false. Of the many persons who are inquiring into the new order of things there are some who see the benefits that accrue by the adoption of the methods advocated, yet there are others who have felt



Automatic Jet Drinking Fountain.
In use in many factories.

that they would rather wait until they could afford to be generous to their employees. But these are being told that success is the outcome of close relationship, and not the reverse. It is this awakening of the industrial world to the touch of the democratic and ethical trend of affairs that is new, and the spread of the thought is rapid. It is the application of these principles, however, that is difficult.

It was easy for the man to whom these ideas were natural to keep in touch with his workmen. But how is the other man

to make the change? How is he going to alter his attitude of aggression to one of persuasion and co-operation? Will he frankly acknowledge his mistake? Will he not at once excite suspicion that he has some new scheme to work? Can he hope to gain confidence by acknowledging that he has not heretofore been deserving of it?

Of course it is impossible nowadays, in most cases on account of their number, for the employer to come in personal touch with all of his employees. The details of this duty must, like all his others, be delegated to the head of a department. But the importance of that department must now be recognized by securing for it as competent a head as is provided for every other, and it must receive the same personal supervision by himself as the others.

Care must be taken to avoid paternalism in the treatment of his people. No self-respecting man will stand patronizing, nor does he wish to be looked upon as an object of charity. Co-operation must be the slogan. Not that kind that expects the other fellow to do all the co-operating, but the kind that extends opportunities for obtaining help. But care must be taken regarding the manner in which help is extended. Helping men in the ordinary sense of the term tends to weaken them, helping them to help themselves develops and strengthens their ability to advance. And it should be remembered that, as most of the waking hours of employees are devoted to their work, the effect of the employers' treatment upon them for good or bad will be great and permanent.

First of all, however, wages and hours of work must be satisfactorily arranged before any schemes of industrial betterment can be proposed. What men work for is money and until their wages are satisfactorily adjusted any reference to betterment of conditions will be taken as a proposed substitute and looked upon with suspicion.

Employees should be allowed to suggest their needs and how the latter should be supplied, rather than that their needs should be pointed out and offers made to meet them. These are democratic principles. In one case the employees ask for what they need and appreciate what they get, in the other they have not wanted what they received, and because they therefore show no appreciation of it they are considered ungrateful.

The time has passed when shops excluded the public for fear of the appropriation of ideas. Nowadays the public is invited to visit the shop, not only as a means of advertising it, but because the public actually supplies ideas to its management. Taking advantage, therefore, of the publicity accorded by representative industrial enterprises, let us visit some of them widely scattered accross the continent and see what they are doing in the nature of industrial betterment. (The speaker then showed about one hundred slides, of which a few illustrations are shown here.)

And now a word in conclusion: Remember that the democratic stage of industrial management has arrived. Do not be afraid to interest the employees in your affairs. The more you can interest them the less apt they will be to work against those interests, especially if you make it plain to them that your interests are theirs also. Men will rise to responsibilities as the latter are imposed. This principle is made use of in the School City where the children of the public schools are allowed to govern themselves. Mr. Gill, who devised this wonderful innovation says: "Give a pronounced radical authority and he at once becomes a conservative." By adopting similar principles the juvenile courts are taking young criminals in hand and by making them part of the constabulary are purifying our cities.

Sound judgment must be used in introducing these democratic ideas. The industrial field is strewn with wrecks of attempts to accomplish the desired end. Do not go at it haphazard. Get some one who has had experience to guide you till you can travel alone with safety. Methods that have been repeatedly applied are successful, but the details of treatment vary according to circumstances, so that what is pertinent in one place is not so in another. A careful study of each case must be made before deciding what to do. Be sure you are right, then go ahead. Bear in mind, however, that you are dealing with the human element, and that your responsibility in controlling and directing the lives of those whom you employ is a dual one, a privilege and an obligation. Being imbued with these ideas you will find plenty of precedent to follow in adopting enlightened methods of treating your employees.

A Trip to Easter Island.*

[A SPECK ON THE OCEAN.]

BY VICTOR STRAUSS FRANK.

PART I.

If you take a map of the world and place the point of your nail upon the Tropic of Capricorn in Chili and run it along the dotted line westward you will find a dot marked Easter Island.

Upon the chart the Pacific thereabouts is not pockmarked with islands or shoals, for Easter Island, or *Isla de Pascua*, or *Rapa-Nui*, or *Téapy*, or *Te-Pito-Te-Henua* claims the honor of being the most isolated island on the globe, being equidistant from *terra firma* for more than two thousand miles; its nearest approach to any Pacific island being Tahiti, some two thousand four hundred miles distant.

Mariners very seldom approach it; now and again a barque bound for the seas of Mexico sights it and notes on her log-book: "Passed Easter I. Lat. $27^{\circ} 10' S$; Long. $109^{\circ} 26' W$."—"Heavy Seas."

Sailors are warned to give it a wide berth, for more than one vessels has been lost on the rocks of this dangerous coast and the crews have been dashed to pieces or have fallen into the hands of cannibals and been eaten. Even of late years skip-pers who have entrusted the handling of their ship to the *Kanakas*, in expectation of being piloted to a safe anchorage and thus enabled to replenish their water supply, have seen, too late, the stratagem of the natives, and their vessel was soon reduced to firewood.

Few men ever visit this Pacific islet, so interesting from many points of view, so much so, as to induce the United States and German Governments to send scientific expeditions there. The romance with which the island of Juan Fernandez has hitherto

*Read by title.

been invested has of late years disappeared before the march of the pioneer; Chili has colonized and peopled it with fishermen. It is doubtful that such a step will ever be taken with regard to Easter I., likewise a Chilian possession, for it is two thousand and thirty nautical miles distant from the coast of Chili, whereas Juan Fernandez is only four hundred miles west of Valparaiso.

In this brief sketch of this, the most isolated island in the world, the extraordinary, the exceptional, the sensational, are not to be found; only a description of one of the least known islands in the Pacific.

Early in November, 189—, great excitement reigned at Valparaiso; the local papers announced that the hull of the "*Maria*," a trading vessel, overdue for more than a year, had been sighted by a homeward-bound vessel, lying high on the rocks of Easter I. The owners lost no time fitting out a ship in order to ascertain whether the hull in question was actually that of the "*Maria*," as well as to pick up any possible survivors. A few weeks later the "*Tortuga*" (truly an appropriate name) was ready for sea. A skipper, well known on Valparaiso quays, two sailors, one of whom styled himself cook, myself and a magnificent dog called Joey formed the relief expedition.

Our departure was somewhat ominous; no sooner had we slipped our moorings in front of Bella-Vista than a series of squalls, gales, hurricanes which followed one another in quick succession forced our craft to scud under bare poles. The skipper cursed and played "rocamber" with the crew; Joey slept; I took a turn at the culinary department!

The "*Tortuga*" was perhaps the greatest rattletrap of a vessel that ever left Valparaiso; she was as hard to steer as a pig, leaked like a sieve, rolled gunwales under at times and eventually lost her fore-topmast. (Overall: 19m80; beam: 6m25; depth: 2m26; draft: 1m80; reg. ton: 88.14; gross ton: 92.77.)

To add to our general discomfort the fresh water supply ran short and salt-junk became too much in evidence on our menu. Notwithstanding our many trials, ten weeks after our departure from Chili we sighted the Rana-Kao mountains in the distance.

Dropping anchor at Hanga-Roa or Cook's Bay, the only pretence to an anchorage, and as aptly remarked by Captain James Cook, "a very poor one," we had the satisfaction of meet-

ing with a friendly reception from the natives, who had swum a mile out to meet us, shouting and gesticulating as they attempted to climb on board. Joey was called to protect us from the too gushing intruders and bravely beat them off, but not until he had left the impression of his molars on the hindquarters of several plump Kanakas. Order being at length restored, we found a sunburnt Chilian in our cabin helping himself freely to brandy and cigars (of the latter he had pocketed a dozen or more). First impulse was to throw him overboard, when, not in the least disconcerted, he introduced himself as "The Inspector-General of Colonization for the Chilian Government," and in a most courteous manner offered us full hospitality on shore. He also informed us that the "*Maria*" had been wrecked on the island, but that four of the crew had been saved.

Easter I. was, after all, not such an inhospitable place as we had been led to expect; officialdom was *en evidence* and that sufficed to induce us to go ashore! Not heeding, however, the warning of the Inspector-General of Colonization for the Chilian Government to trust our persons in a native canoe, we put off in our only whale-boat, which was manned by three Kanakas. The shore was enveloped in a dense mist and, what with the roar of the surf on the bar, the boat rocking as in a churn, the impression was far from pleasant for a land lubber. Suddenly a wave more erratic than the rest came rolling and gambolling along and breaking alongside of us caused our boat to capsize. Words cannot express our disgust (delight on the Kanaka side) when we found ourselves in the water; the European swearing shockingly as he saw the valise containing his personal wearing apparel disappearing; second thought prompted him to look after No. 1, when the recollection of having seen sharks at sea flashed across his usually dull brain. Abandoning worldly possessions we made for shore, no easy matter, for the sea was rough. When we reached shore, much bruised, the Kanakas were disputing as to the distribution of my belongings which they had rescued. Two shirts were already turned into eight ladies petticoats. Happily the Inspector-General of Colonization for the Chilian Government saved me from the unpleasant prospect of visiting him in a nude condition by forcing the Kanakas to restore a portion of the contents of the valise, which that did with ill-disguised regret. I had, however, the satisfaction

of saving a collar, one sock and a handkerchief. I blessed that 'kerchief. Very tired, ill-tempered, we were all dragged to the Mission House, or rather to the remains of what was once upon a time a mission station, at a place about one and a half miles from Hanga-Roa. Here the crew of the "*Maria*" were discussing the event of our arrival. The lazy scamps had been on the island nearly a year, feeding upon the fat of the land, awaiting the time when a vessel should come to pick them up. Upon learning of our arrival, their satisfaction was so small that they did not trouble to walk down to the shore to meet us. At Valparaiso masses had been held for them and candles burnt *ad. lib.* Next morning, with rueful countenances, they were sent aboard the "*Tortuga*" and peremptorily ordered to assist in repairing the schooner, which was so badly damaged that it would require at least a fortnight before she could put to sea.

PART II.

Any position more lonely than that of Inspector-General of Colonization for the Chilian Government at Easter Island is impossible to conceive, and it requires a vigorous effort of the mind to believe that a man can be found to live on this remote island with Kanakas, dependent on a few passing ships for news, tobacco, matches and clothing, for the sum of 10 dollars per month. When Mr. X, a Valparaiso merchant, leased this island from the Chilian Government for a period of twenty years, paying annual tribute, and pledging himself to look after the welfare of the Chilian subjects on the island, and send a vessel there at least once every two years, he was at a loss whom to send to look after his interests. He advertised, and in response came Mr. A. This gentleman was accepted, being a man of no mean capacity, and in order to inspire his future subjects with some idea of his elevated functions as Viceroy of Easter Island, he obtained a commission from the Santiago Government appointing him Inspector-General of Colonization for the Chilian Government. Mr. A. started off in high glee and with the best wishes from his newly married wife. Poor fellow! for no sooner had he arrived on the island than he discovered his post to be no sinecure, and to add to his chagrin, found his official position ignored by Riro-Roko, King of Easter Island. Some

weeks later Mr. A. was obliged to exchange his resplendent uniform for wood; a month later he was at "dagger's drawn" with the King, who forbid him to wash in soft water—not even once a month. Mr. A. found he was responsible for the care of immense herds of cattle, horses and sheep, roaming wild over the island. He found no dwelling and had to run up an apology for a house, which was built off the ground upon hewn stone slabs, three feet thick, forty-five feet wide and nine to ten feet long, evidently the remains of an altar erected by an extinct race.

The panorama which this shanty commanded, situated at Mataverí, near Hanga-Piko, is most picturesque. The Inspector-General of Colonization for the Chilean Government passed his time eating, drinking and sleeping; he attempted to cure green tobacco, which grows on the island, and made a signal failure. He had books, but never read. His indolent disposition forbade all agitation of a topic whose interest he himself had never existed, namely, the curious and weird remains and ruins on the island. It may surprise the reader to learn that this very worthy official had never troubled to go round the island, much less ascend the craters or examine the ruins. And, to those who love a long record of an official's faithful services to his country and who have not yet learnt of the degree of *dolce far niente* a Chilean is capable of, this genial personage may be commended as a pattern official second to none.

Easter Island presents nowadays, from many points of view, a totally different aspect from that offered at its discovery by Jacob Roggwein, the celebrated Dutch navigator, who on Easter Day, 1722, with three vessels, the "Eagle," "Tienhoven" and "African Galley," carrying 271 men and 78 guns, accidentally came across this remote island which the Dutch commodore mistook for the supposed existing "Southern Continent," the inaccurate theory thereof being proved by Captain James Cook some years later. Roggwein mentions that the island was extremely fertile and densely populated, having about three thousand inhabitants. The natives, he writes, received them in a most friendly manner, offering the visitors sugar-cane, plantains, fowls and birds of every shape and hue. He says that the men were six feet in height and were pleasing

and modest and well disposed, a fact which did not prevent the Dutch from firing upon them and killing several.

The men—relates the navigator—were in the majority brown, others partly black, some white, and the latter fact appears to have made a deep impression on Roggewein, who was certain that the “*terra nondum cognita*” was not far distant, as Juan Fernandez was reported to have discovered in 1576 a “gran tierra firme, fertile and pleasant, the natives white, clothed in woven fabrics.” Roggewein informs that the inhabitants were tattooed all over the body, the men in black, the women in blue and red. The ear-lobes of both sexes were exceedingly long and hung down to their shoulders, which he accounts for from their wearing very heavy ear-rings. The men let their hair grow long, the women likewise. Native huts, he describes, as being from forty to fifty feet in depth, six to eight feet in breadth. Roggewein noticed that the natives lighted fires at the feet of the Monoliths to appease the wrath of the visitors, also that they carried crescent-shaped shields, having human figures carved on the cusps. Space does not permit to dwell more at length on Roggewein’s report. If we may rely on his statements, Easter Island was then as fertile and densely populated as it is now scantily populated.

Captain James Cook visited this island in March, 1774, and mistook it for Davis’ Land, supposing it to be a certain island mentioned by Davis as discovered by him. Spanish writers claim that this island was first sighted by the Peruvian sailor, Alvaro Mendana, in 1566; others assert that Davis was the discoverer. But what is certain is that neither landed, leaving that honor to Roggewein. Captain J. Cook mentions: “This small island has only seven hundred inhabitants, of which fifteen are women, and the island will soon be depopulated.” Thus, in the space of about fifty years, the island had assumed a striking transformation, which must be attributed to a visit to Easter I. by the Peruvians in 1770, when Philippe Gonzalez with two ships, the “S. Lorenzo” and “Sa. Roselia,” took possession of the island in the name of Carlos III and gave it the name of the King, when a deed of possession was signed by the Kanakas chieftians, who employed hieroglyphs. The Peruvians, prone to cruelty, ravaged the fair island and in addition spread venereal disease throughout; carrying off the young

girls and fair women. La Pérouse visited Easter Island in 1786, followed by Kotzebue in 1816, Captain Beechey in 1826, by the Chilian warship "O'Higgins," by Father Eugenio Eynault and Roussel in 1863-65, by Captain Poweill in 1868, by Commander Viaud in 1871, by Admiral Lapelin in 1872, and by Mr. Thompson, (U. S. N.).

Most of the visitors, apart from Mr. Thompson, have little to say about the island, save that of praising the colossal monoliths, and more particularly the hospitality afforded to them by the ladies. It is said that some thirty years back a Frenchman had been wrecked on the island; he was not eaten for when surrounded by the natives he addressed them in Tahitian and informed them that he was a great King, that he would, however, condescend to present one of his trouser buttons to the head man of the island, but upon the express condition that no harm should be done him. Thundering forth he gave vent to a well-disguised outburst of temper, menaced that if a man dare touch him, he, Pitou-Pitou, would kill every woman on the island. His speech produced an electric effect. Pitou-Pitou, as he was affectionately called by the Kanakas, soon gained complete mastery over the island; he enticed small vessels bound for Tahiti on the treacherous reefs, scuttled them and handed the half-drowned crews to the Kanakas for culinary purposes. With the broken-up ships he built two small schooners, put a Kanaka crew on board, and traded with Tahiti, over two thousand miles distant. The French adventurer was ultimately killed by one of his many jealous wives. But his memory was for a long time cherished by all Easter Island.

We pass over in silence the occupation of Easter Island by a Tahitian firm, who deported, it is said, three hundred Kanakas to Gambier Island and five hundred to Tahiti. None returned to their native island. In the early eighties a certain Mr. B., who married a Queen of Tahiti, appears to have taken possession of Easter Island and to have sold it to the Chilian Government for the sum of 10,000 dollars, but as to the veracity of this deal I cannot vouch. The Chilian Government, *chose certaine*, occupied it, it being their intention to establish a coaling station there were vessels, en route for Australia, *via* the Panama Canal, could replenish their bunkers. The Chilians had counted their chicks before hatching, but at the time of the deal

our readers will bear in mind that the success and rapid completion of the Panama Canal by De Lesseps & Co. was assured. The Panama Canal, 15 years later, is not finished and Easter Island is left on the hands of the Chilian Government, which, after attempting to establish there a convict station, finally leased the island to a Liverpool firm, the previous occupiers having failed to pay their rent. Easter Island, in 1905, is, however, as lonesome and as much ignored by the world as at the time of its discovery.

Isla de Pascua is in the shape of an isosceles triangle with an area of about thirty-three square miles and four miles broad at its widest part. Although the island can nowhere boast of a shelter from the prevalent winds worthy of the name of harbor, yet it is surrounded by a shelving beach which at a distance of about one English mile from the shore provides a fairly good sandy anchorage interspersed with thin shingle at a depth varying from twenty-five to thirty fathoms. It is a clear coast for a mile out with the exception of the southwest point, where two small rugged islets, Mutu-Rau-Kau and Mutu-Nui, some ten cables from land, can be seen for about twelve miles off. In most places access to the shore is rendered risky by coral-reefs. A vessel can find fairly good anchorage to leeward of the island at a distance of about a mile, but precautions should be taken to enable it to put off at a few minutes notice should the wind change. Hanga-Roa, or Cook's Bay, and La Pérouse Bay afford the most security. At Hanga-Roa is situated one of the two mission stations, but in a sad state of dilapidation. This bay is not much cut out, has a bottom of fine sand, and a steamer can safely approach within half a mile from shore. There are sheltered stations, in good weather or with winds from 1st and 2nd quarters, which are the only ones allowing ships to remain in port without danger. During the winter months, or from April until October, Hanga-Roa is to windward, and it is unsafe for a vessel to remain there; the winds at this period, blowing from the 3rd and 4th quarters, are tempestuous, raising a violent sea which dashes on the rocks. La Pérouse Bay is an open stretch, two miles long, with half a curve in the most sheltered places. It offers an even bottom of the same character as the rest of the coast and a good anchorage, more exactly a "fair" anchorage, may be obtained there in

seventeen fathoms, but prudence commands standing out farther for fear of a change in the wind. Close to La Pérouse Bay, following the coast to the west, is to be found a white sandy beach, enclosed in a small bay, known as Anakena, which allows every facility for landing. Anchorage may also be found at Vai-Hou, situate in the base of the triangle, where the other mission station stands.

There is practically no tide, at any rate not exceeding one-half meter. The water surrounding the island, at the same degrees, in the same parallels, contains a greater proportion of solids than in many other latitudes. From experiments, samples taken in, gave:

Lat. 28° S., long. 98° W., 3.85 % of solids.

Lat. $27^{\circ} 10'$ S., long. $109^{\circ} 26'$, 3.91 % of solids.

These results which surpass the saline part of the known ocean, estimated at $3\frac{1}{2}\%$, may depend not so much on the dense evaporation of the Pacific in this zone as in the organic residues which the Polynesian waters contain and where extensive animal life and especially corals pile up vast coralline accumulations which rise day by day with wonderful rapidity, obstructing passages heretofore navigable.

The climate of Rapa-Nui is interesting from various points of view. The island is washed by a warm current some nine degrees higher than the polar current (Humboldt) which washes the Chilean coast, and it keeps a higher temperature than Caldera and all the ports of the desert of Atacama comprised in its zone. The temperature of the air is generally one degree less than the sea so that the heat is about even day and night. Frequent rains refresh the atmosphere and the ground. The following data taken by missionaries may give a general idea as to the rainfall: April, 2 days; May, 15 days; June, 10 days; July, 15 days; August, 13 days; September, 11 days; October, 5 days; December, 5 days; January, 1 day; February and March, no rainfall.

Rainfalls are brought by N.; N.W.; N.E.; E. and S.W. winds. Incidentally we might mention that the statement made by some writers that the natives of Easter Island drink salt water in lieu of fresh is erroneous. They do drink sea water as a purgative. Easter Island is in the zone of descending clouds which, coming from the Northern Hemisphere, bring their moisture

south. All clouds which pass within reach of their attraction, collect on the peaks and condensing there, irrigate this isolated island, which has in its mountains the necessary physical conditions for precipitating the water of the atmosphere. One of its summits, the Rana-Hana-Kana or La Pérouse Mountain, is 1769 feet high; the Rana-Roraca or Mt. Topaze, 1542 feet; the Rana-Aroi or Mt. Beechey, 1323 feet; the Rana-Kao, 1327 feet. Although these elevations are not high enough to produce much rarefaction of the atmosphere, they are nevertheless sufficient to refresh the air at their summits, causing a condensation of the tropical clouds which, having passed the heat of the equinoxial doldrums, descends between the parallels which bound the temperate zone in which this island is situated. These rains, which obey the natural laws of nature, would augment with the cultivation of the island and suffice to maintain vegetation. The Kanakas rely upon natural reservoirs formed in the craters for the collection of water. The temperature in winter averages between 19-20° Cent.; sometimes as low as 16° Cent. The temperature in summer is between 26° Cent. and 29° Cent. Frosts are unknown; hail has been seen; cyclones are unknown.

For miles out at sea one is at once impressed with the mountainous nature of the island. Indeed Easter Island is remarkable for the agglomeration of volcanoes in so circumscribed an area. The island is volcanic, still, it may have formed a part of a once existing continent. The volcanoes known as Kau, Utuiti and Harui appear to have been extinct for centuries, the craters, some twelve in all, being covered with rich vegetable soil. Kau is the largest crater and nearest Hanga-Roa. It is about three hundred meters deep and the bottom as smooth as a skating rink, and the only way to account for its perfect level is that it was gradually solidified when the lava was in fusion or perhaps by the action of the sea.

Good soil is found nearly all over the island and in many places pits of vegetable soil are to be found as deep as ten meters. There is a layer of soil nearly all over the island. On the northern side sandy patches are found in thin soil where the Kanakas prefer to sow their sweet potatoes and yams. Within two miles around the craters stones are abundant in the earth and were formerly employed for the construction of huts by lay-

ing them one upon the other. There is a total absence of trees, although Roggewein spoke of palm trees. Indeed the absence of that vegetation, which one looks forward to and associates with the perpetual summer of these regions, makes Easter Island anything but inviting to the naturalist. Grass grows on the mountain slopes and in the valleys, affording pasturage to about five thousand horses of Chilian breed, five thousand horned cattle, twenty thousand sheep, the latter yielding very fine wool and lambing twice or thrice a year.

It is around the gaping chasms or fire-eaten pits of the extinct volcanoes—which, in the memory of man, have never been active, now forming reservoirs for the natives—that is found a luxuriant vegetation, growing on the perpendicular walls and at the bottom. Here a few, very few, industrious natives cultivate sweet potatoes, yams and bananas. Apart from these are found three shrubs of great utility known as Ma-huté, Borahue and Tii. The Ma-huté is a small shrub which dries up in summer to revive at springtime. It gives a stronger fibre than cotton and is woven by the natives into a strong, white texture, warm and smooth to the skin. It resembles the *Phormium Tenax* of New Zealand. The Borahue, a shrub, grows about $2\frac{1}{2}$ meters high and eight centimeters in diameter; it produces a fibre-like flax which is used for string, and fishing nets, as it stands sea water well. The Ti or Tii, common to hot climates, is also abundant. The root is in the shape of an elongated bulb and is sweet, giving more sugar than the cane, which also grows on the island and is used by the Kanakas as fuel. The root of the Tii is roasted on hot stones laid in the earth where it remains several days, and, when cooked, it makes a very delicate and tasty meal. This same Tii also yields a black powder from the flower, which is employed for tattooing. The only wood found is that known as Toromiro, which, it is stated, is related to the Australian acacia. This small treeling, also called Amae, is of a reddish color, hard, heavy, crooked and does not exceed seven feet in height and the largest one-half meter in diameter. All the wooden images and few other wooden implements found on this island are made of toromiro. The zoological section is uninteresting—only rats, sea gulls and, in entomology, fleas *ad lib.*

Round the south promontory are found huge quantities of

lobsters; they are much larger than those taken in European waters, of a deeper hue, and are furnished with prickly spines. There are but few fish on the coast line. The *cotehiva*, about 30 centimeters by 80 millimeters broad, with canine teeth; the *coveba*, about 25 centimeters by 0.65 millimeters, with no scales and a bony horn about 0.30 millimeters long in the nape of the neck. There are also flying fish and nautili. Seals or whales do not appear within ten miles from shore, probably on account of the warm currents. Turtles are abundant. There appears to be no animal indigenous to the island, but it seems that when Roggewein showed the natives some pigs he had on board they made signs that they had known this animal at some previous time. Moreover, some of the antique carvings on the wooden slabs and rocks represent hogs, birds and lizards.

Mineral wealth is absent; no traces of carbon. Here and there are found crystalline limestone and obsidian. Obsidian, according to the natives, is a gift of God to enable them to make axe-heads and chisels, but the idea of adopting them for warfare among themselves has never entered their heads, the only weapon observed apart from clubs being a quaint looking sword of "toromiro wood," two meters long, the pommel representing a god. Very heavy and sharp, this sword when wielded by an expert hand must have been somewhat dangerous.

PART III.

No opinion is formed among ethnologists as to the origin of the present generation of the Kanaka of Easter Island, and all one can venture to say is that they are fair Polynesians. The Kanakas, as the natives of this island are styled, are, the male portions of them, of fine physique, of good stature, but under six feet, slight limbed, brown black hair, rather flat noses, thickish or rather swollen lips, and good, even teeth, large hands and feet.

The women are beautifully proportioned, full of grace and other feminine attractions. Indeed we are disposed to assert that the Kanakas of Easter Island are the remaining portion of a once highly refined race. When Roggewein discovered the island there appears to have been nearly three thousand inhabi-

tants. Captain Cook estimated the population at seven hundred, but it is probable that many of the natives had retreated to hiding places, fearing lest the new comer should ill-treat them as had the Dutch and Peruvians. In 1786 the roll-call gave two thousand inhabitants; in 1863, eighteen hundred; in 1868, nine hundred and thirty; in 1885; six hundred; in 1897, only two hundred and thirteen. Polyandry, disease, emigration, alas kidnapping, have rapidly carried them off. The first practice cannot be stamped out for reasons known to the medical world. Brothers and sisters intermarry. With regard to disease, the present inhabitants are healthy, but they passed through a terrible period after the return of many of their countrymen from the Chincha, converting the island into one huge burial ground.

In 1863 the Peruvians made a descent and carried off no fewer than nine hundred natives, including the King and chiefs. The poor wretches were sent to the Chincha to work the guano fields, the women taken to Peru and when wearied by lust were sent to rejoin their countrymen. The captors ill-treated them so shamefully that a captain of a French vessel reported the atrocities to which they were subjected, to his government, which compelled the Peruvian Government to ship the Kanakas back to their home where, as the King and chiefs had been taken off into captivity, civil war thereupon raged, each trying to obtain supremacy. The King died on the guano fields, and the two hundred natives who did return were a curse for the island, as they were ravaged with hideous diseases and alive with vermin.

Frugal in their habits, their chief staple food is of a vegetarian nature. Too lazy to cook, they rarely touch mutton or beef, which are plentiful, and usually eat their fruit and vegetables raw. The cooking utensils are of the rudest description, even gourds or cocoanut shells (much prized) being rarely employed. Fingers, in lieu of forks, direct "plate" to mouth instead of spoons. They love spirits. Their resentments, though violent, are soon appeased; they are not cruel even when aroused to anger, and the island is singularly free from bloodshed. The men pass their time lolling in the sun, fishing and smoking; very few cultivate the ground; husbandry is at a very low ebb. All are expert riders and delight in breaking in the horses which roam wild over the island.

The native tongue is soft to the ear and is similar in some respects to Tahitian which the Kanakas understand. The language of Rapa-Nui only has the pronouns "I" and "You." The verbs are only conjugated by three terminations. There is no word sounded with two united consonants so the vowels repeatedly form diphthongs and triphthongs. Double "R," "W," "X," "D," "B," "S" are unknown. No word terminates in "N." To make the plural they prefix "Mau," which means "many." To form the feminine they add "toma-hina," or masculine "toma-toa." The language appears to be as easy as it is limited; they are all great talkers. They do not ignore the art of writing, the present generation having been taught by missionaries, but few can sign their names. They point out with pride to the rare hieroglyphics carved on some altar-stones, or stone slabs, but are at a loss to decipher them or to account for their presence. Several of these slabs bearing hieroglyphic inscriptions have found their way to the Museum of Santiago, Chili, presented by Father Eugenio Eynault, and one to Paris, given by a Bishop of Tahiti. They are said to refer to prayers offered to the gods and the Great Father, but the version should be subject to caution, this statement being made with all due deference for the savants who have "translated" these Easter Island hieroglyphics.

Marriage among the Kanakas is a somewhat unrefined ceremony; men have only one wife, but are promiscuously licentious. Girls are kept in strict seclusion until the age of twelve, when they are claimed by the chiefs. Women have rarely more than one child and appear to be devoid of maternal love, it being a common event for a woman to dispose of her child for a piece of cloth or even for the mere asking by another woman, yet children are never ill-treated.

Subsequent to 1863 the natives of Easter Island worshipped different wooden idols or images, but not the Monoliths or Mohias which some writers mention as being statues of famous warriors rather than of deities. But on account of the resemblance of their masks, which are almost identically the same, this argument appears worthy of challenge. Their religious feasts it appears took place when shipwrecked men were cast on the island and were carried off to the sacrificial altars, usually situated at the end of a grove of monoliths. These stone-altars,

found all over the island, but especially at Rana-Kao, Vahio, Utuiti, are of immense size and made of hewn slabs carefully placed side by side, or cemented together or piled one upon the other. A few are embellished with hieroglyphs. That human sacrifice was practiced is certain; the natives do not hide the fact and inform by tradition. The numberless skulls found at Utuiti, however, do not necessarily tell a tale of cannibalism, for it was also a burial ground. Tradition says that human sacrifice constituted their highest form of worship, which one must infer was only celebrated at rare intervals, considering their isolated position. When questioned on their toromiro idols, which they carefully hide notwithstanding their departure from idol worship, they can give no answer. The idols are some, single-headed, others, very scarce, double-headed, such as the one to be seen at the British Museum. The Kanaka never was of a stubborn disposition and much less a fanatic, and when a Bishop of Tahiti sent Father Eugenio Eynault to visit the island in 1863 the worthy man met with signal success. Upon landing he was forced to make a prolonged sojourn, as his vessel had disappeared during the night, the captain remarking to the mate that it was no safe place "for a ship or Christian." As it was Father Eynault was at once stripped and his life was only saved by the intervention of a chief. Some eight months later the Bishop of Tahiti, anxious as to the fate of his messenger of peace, sent another vessel and took him off, but the worthy Father returned two years later accompanied by another colleague, Father Roussel. The two priests worked miracles, built churches, baptized, opened a school and succeeded in forcing the Kanakas to abandon idol-worship.

Cannibalism is a practice of the past and only the very oldest men remember partaking of human flesh. Only the "Elders" were allowed to assist and came singly to the sacrifice-banquet, by different routes, at night. It was under the shadow of the huge, massive, ferocious looking monoliths that the victims, always captives or shipwrecked sailors (often Peruvians) were eaten. Wood was brought and placed at the feet of the giant gods for bonfires, so as to illuminate their strange, weird masks. At daybreak the orgy would cease and the revellers departed, making strange gestures before the clean bones and crowning

the "hats" of the monoliths with sea weed when palm branches were no longer to be found on the island.

One of their chief amusements (they love pleasure) is dancing. Men and women, young and old, gather under a grove of monoliths and, in a line, and to the strains produced by beating two sticks together or hammering on sheep skulls, dance with their knees rigid and wagging their hips in a violent manner. This pastime is in other terms a mode of seeking artificial physical excitement, but this the dancers sternly deny, asserting that it is to honor their forefathers. Tattooing is practiced, but not in so general a manner as in other Pacific islands; the custom is rapidly falling into disuse throughout Polynesia. The French Government, for instance, some years back issued a lengthy decree (proclamation) forbidding their Polynesian subjects to tattoo their bodies, and a heavy penalty is inflicted on law-breakers. The poor Polynesians now go about as naked as worms. Tattooing was a "costume." The Easter Island natives have, almost without exception, on their left cheek, the figure of a pipe in blue pigment. In the way of head dress (the chief ornament of a South Sea Islander) the beaux of Easter Island in past times were not behind other aborigines in adorning their heads with brilliant feathers, for it appears that they wore bonnets of black and white feathers of endless hue in the shape of the head of a stork. Since birds of gorgeous hue and plumage have taken their departure, the natives have to make the most of sea gulls and cock feathers, which they make up in two or three strings simply coiled around their heads. Unlike the natives of Tahiti and other Polynesian islands, owing to the absence of trees, they have not been able to indulge in the pleasures of navigation, and it has been perhaps for their good, their isolated position keeping pirates away. There are but three canoes, or pretence to canoes, built of planks from wreckage. It is highly amusing to watch them paddling in their rudely constructed crafts, then suddenly become tired of that mode of locomotion, and jump into the sea and swim to shore. Yet they make good sailors and are ready to embark on passing vessels as a part of the crew, making steady seamen, and useful in warm climes. They are all expert swimmers and fine divers, remaining under water for a remarkably long time. It is one of their principal amusements to dive after lobsters which they eat raw.

Although sharks infest these waters, not one instance of a Kanaka having been eaten by these finny monsters is recorded, but many with an arm or leg missing tend to prove that they were very near to it. Fish-hooks are made of bone and stone; although tortoise shell and pearl shells are found on the islands (more exactly on the two islets) the natives do not appear to make use of them. Unlike other South Sea Islanders spear-fishing is not practiced by them, probably owing to the depth of the water around the island and because canoes are scarce.

The King of Easter Island at the time of the visit of the "*Tortuga*" was Riro-Roko, who had paramount power over his subjects. He prided himself on his ancestry, which dates back many generations. He was a fine looking fellow about thirty, and, like his subjects, the very essence of laziness. Troubling little about his regal position, he inhabited a small hut at Mataverí where he watched the movements of the Inspector-General of Colonization for the Chilean Government for whom he showed the utmost contempt. In this hut he had stored his fishing net, clubs, gods, old iron, planks, hides, wool and perhaps, involuntarily, a formidable army of fleas.

Once upon a time the Kings of Easter Island, of which a lineage is preserved, were not allowed to be touched by a third person, being regarded as sacred. Moreover, their hair was never cut, a mark of royalty. It is related when the Peruvians kidnapped a large portion of the islanders, including the King, they left behind his only son, a boy of four, who, overcome with grief at being separated from his father, fell desperately ill. So critical had become his condition that a native woman who was nursing him in order to alleviate his sufferings wanted to cut off his long hair. The child protested in so earnest a manner not to be deprived of his emblem of royalty that the woman acceded to his dying wish. This was the last of a race of kings which had governed Easter Island for some two hundred years. Decadence! The present king allows his hair to be cut—he has not much at any rate—he dives after lobsters in common with his subjects, and is the king of swimmers if nothing else. While on this matter we might mention that the Easter Islanders nowadays elect their chiefs annually; this event giving rise to a curious competition upon which depends the election of the Chief of Chiefs. It is the candidate which finds the first sea gull's egg

of the season during which the election takes place who is chosen. Of course fraud is not absent. Another point, it has been alleged that in olden times the monarch abdicated on the marriage of his eldest son; this statement on good authority is inaccurate.

Apart from heavy clubs of toromiro, which they leave at home when no stranger is on the island and which they hide if otherwise, the Kanakas have no weapons and display fear in presence of firearms, but they have nevertheless a marked affection for other people's knives.

Earthenware is eagerly sought after; a basin, a pitcher, being given to the king he set his wife to break them up in small pieces, obviously to increase his acquisition by the quantity of potsherds.

Men and women go about in a semi-nude state, only married women wearing a pretence of a Polynesian breech-cloth made of "tapa" or "mahute." They are most anxious to obtain bright woolen shirts and stuffs, for what purpose, we ignore, as they never wore them. The Kanakas are not thieves, *à la Euro-péenc!* They take what they can lay their hands upon in so impudent, cool a manner and with so solemn a look, that all pretence to "lifting" on the sly is assuredly out of the question.

Whence come they? The Kanakas give two versions with regard to their origin and these traditions they readily admit are doubtful—a Kanaka never troubles himself to argue. The first is that the founders of their race came, many cycles back, in four ships with raised poops and prows, under the command of a king, Hato or Incuyo. The men were of mighty stature, and when they had landed put the head of a decapitated maiden at the prow of each vessel, which immediately plunged under the foam. The second tradition relates that thousands of generations back a migration took place from Oporo or Rapa-Ita, one of the Low Archipelago; hence they call their present abode Rapa-Nui or Great Rapa to distinguish it from Rapa-Iti or Little Rapa. Incuyo divided the island and women among his followers.

The question has been asked how came those three hundred or more statues, from five to fifty feet high, placed in position all over the island, or ridges, on the edge of overhanging cliffs, on stone-platforms, in the midst of altar groves, in recesses;

sometimes alone, or in groups from four to thirty? These monoliths are carved out of stone, some of trachyte lava, nearly all presenting the appearance of *torsos* terminating at the hip, sometimes with arms close to the side, now and again with hands sculptured in low bas-relief on the haunches. The head is flat, the top being cut off level to allow a "hat" to be put on. These "hats" are usually round and carved out of red tufa. In most cases these head-gears have rolled off and lie beside the giant monoliths as if the gods had cast them down in despair or rage at the decadence in their worship. The faces, generally speaking, are square, massive, disdainful in expression, the aspect always upwards, the lips thin, the upper lip short and the lower lip thrust up. The eye sockets are deep; in former days balls of obsidian were inserted; giving a terrible expression to the giants. At present, the eye sockets form a nest for birds. The nose is broad, the nostrils expanded, the ears with long pendent lobes. At Utuiti, the most curious features of the island presents itself in three stone platforms, crumbling away. On each side eight monoliths, some sixteen feet high and about seven feet over the shoulder, stood side by side. At present they are nearly all upset and broken. These mohias at Utuiti, described by Captain James Cook, are by no means the largest, for at Rana-Roraca, Hanga-Roa, Rana-Kao, Ponapav, Rana-Hana-Kana and Vai-Hoo, some measure not less than fifty feet and more. At Rana-Hana-Kana there are twenty-three made of hard rock and in a perfect state of preservation. At Hanga-Roa, the greater part are upset and children amuse themselves chipping off the noses, ears and inscriptions.

A few bear traces of carvings representing birds, axe-heads, paddles and occasionally, animals. Of these monoliths, but very few have found their way to the Old and New Worlds. One is to be found, I believe, at the Santiago Museum, Chili; one at the British Museum, London, brought over by a British man-o-war and presented by the late Queen Victoria to the nation; another, brought over in 1870 by a French frigate, was found by Mr. Edwin S. Balch stowed away in a shed of the Paris Jardin des Plantes surrounded by a lot of old scrap iron and rubbish. Describing his "discovery," Mr. Balch says: "One of the most extraordinary works of art in Paris is the colossal head from Easter Island, now in the *Jardin des Plantes*. It is about

six feet in height, with a great, highly-modelled nose, deep cavernous eyes, a tiny slit of a mouth and a strong square chin. The ears are long, but not much worked out. There is scarcely any head back of the ears and a very low forehead. It almost seems as though the head was only intended to be looked at from the front. It is most dignified, neither childish nor savage, but decidedly advanced art. * * * "

Nowadays with all the engineering appliances at command it would be impossible to move many of these monoliths. There is absolutely no trace of metals on the island; there is no timber, no cordage; the island is more than two thousand miles distant from its nearest neighbor, Tahiti. It is impossible for these large masses of rock to have been broken off in such equal proportions and after having been carved, carried to their destination, for many of them weigh certainly more than two hundred tons.

Who were the sculptors whose work is surprisingly far from being rough or unskilled? Their work is as curious as the Idols and Temples of the Sun in Peru and Mexico and Guatemala, as the dolmens in Wales, the Pyramids, the giant temples of Luxor and Memphis, the towering gods of the Bhotan; more so, when we consider the geographical position of Easter Island. Another question arises, to what purpose, and by whom inhabited, were those stone caverns, in the shape of an inverted canoe, three feet high, three feet wide and from three to forty feet long? The most obvious agent in hollowing out caves, we know, is water, but these rock hollows, if not made by man, were formed, we are inclined to believe, by the passage of lava to the surface of the ground or by the imprisonment of steam and gases in the lava while it was in a molten state. Yet in spite of our doubts as to whether these caverns were or were not the work of a prehistoric race, we are forced to admit that our perplexity is great upon finding the entrances of these caverns guarded by a stone door. Inside there is no trace of their having been occupied, except a few scant inscriptions and figures and in some a sealed pavement which shows evident proof that this once served for some purpose, for when opened it revealed under the entire length of the passage numerous deep pits. In others, large quantities of univalve shells were found, and in one, a monolith differing from the others to such a de-

gree as to render it more interesting still. Roughly estimated, it weighed about fourteen tons and was eight feet high. In no instance has there been any trace found in these caverns of gold, silver, brass. They are empty.

Much attention is directed to the stone houses or huts, mostly fallen in ruins, made of stones laid one upon the other. These evidently are not so antique as the caverns.

Of wooden images or idols there are a few yet found, but they are jealously guarded by the old natives as relics of a past age. These idols in which the vertebrae and ribs are very pronounced, have strong semitic features and have none of the solemn repose of the colossal monoliths. The worship of wooden gods was much later than that of stone gods. Slabs of toromiro wood bearing hieroglyphs are likewise found and have been dwelt upon at length by the learned world. The wooden tablets are about fourteen inches long by five inches wide and one inch thick. One "specimen" is at the Santiago Museum, another at the British Museum, another in Paris. We pass over in silence the long stone passages, now in ruins, leading down to the sea. Were they the roads leading from a royal palace?

Some day perhaps Easter Island will hold a prominent position in the history of lost races. For it is here that the gigantic monoliths, curious hieroglyphs, caves, etc., offer a thread, binding the past with the present, a link all the more interesting when we consider its unique geographical position. During cycles of centuries the now extinct race must have advanced towards a high degree of civilization, not in the mind of the trader or missionary perhaps, but certainly of the artist when the latter contemplates the mohias which seem to point to a period when a powerful race lived on that island; then, perhaps, a continent, if no longer so in the times of Davis.

Tradition does not reach to that remote past; alone the monoliths are all that remain to bear evidence of a lost and mighty power of human labor, of art, of skill, of immense conception.

Naught have we learned of the prehistoric race. The natives also, who now inhabit Easter Island, are so little known that they are well worthy of the interest of the ethnologist. Their undoubted antiquity and ancient language, all combine to render them a peculiarly interesting race.

Once more the noble "*Tortuga*" stood on her course in the open sea.

SMELTING IRON ORES BY ELECTRICITY IN NEW YORK STATE.

Titaniferous iron ores, the geology of which has been studied by Prof. F. Kemp, of Columbia University, occur in the United States in "immense deposits," "in mountain masses" in the Adirondack region. They are "one of the most marvellous deposits in the United States." They are also found almost as abundantly in Minnesota, Michigan, Colorado, North Carolina, and most everywhere in the United States, and also in Canada, Sweden, Norway, New Zealand, Russia and other countries. In many districts, such as the Adirondacks, for instance, they could be mined for years in open quarry, constituting, as they do, the geological formation itself.

They are very rich in iron, containing 50 to 60 per cent. of metallic iron, are low in sulphur (0.025) and phosphorus (0.017), and also in silica (1 1-2 to 2 per cent.), with about 15 per cent. of titanitic acid. Occurring in an igneous formation implies their being found in mountainous districts that are precisely in regions where it is possible to generate electric power for smelting purposes at a minimum cost. Lakes of 3 to 4 miles in length by 1 1-2 to 2 miles wide, with falls of about 60 feet from one to the other, are found, for instance, with a number of others of lesser dimensions, in the districts from which the writer has drawn much of the ores used in the manufacture of alloys. Charcoal can be had at a very low cost, limestone or other suitable fluxes are within easy reach, and the product, pig-iron, could follow a down grade to the tide water.

The writer has quoted this region with some details merely on account of its being familiar to him. But in many places in Canada and elsewhere similar ores occur also in abundance, being even available by means of water or other communication, and there, as in the Adirondacks, could be created locally an iron-smelting industry with conditions of economy particularly favorable.—A. J. Rossi, in *The Electrical Age* for June.

CALIFORNIA TURQUOISE IN FAVOR.

The turquoise mines of New Mexico and Arizona have lately not been as productive as formerly, says Mr. George F. Kunz in a report on the production of precious stones in 1905, which the United States Geological Survey will soon publish. The turquoise properties of California and Nevada have, however, been increasing their output. Considerable quantities of turquoise have been taken from the mines in the desert region of San Bernardino County, Cal. Many of the stones range from 50 to several hundred carats in size. Some of them have sold as high as \$1,500 each. The color is pale, but it has gained favor, and large quantities of the stones have been sold in the form of beads for necklaces.

(*Stated Meeting, held Wednesday, March 15th, 1905.*)

Regulation of the Duration of Combustion.

BY BYRON ELDRED, B. S.,

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The subject of my talk is an abstruse one at best, and I am going to start by disclaiming any intention of carrying you into the realms of theoretical chemistry or to burden you with charts and intricate mathematical calculations.

I am going to tell you about the conception of the idea for flame regulation and the development of this idea and its practical application to several arts.

The main object of my talk is to demonstrate the difference between the use of pre-generated heat and the use of a heat-producing agent or long flame which results in the generation of the heat where it is to be used. This may be quite properly classed as the regulation and control of the duration of combustion and of the temperature and volume of the flame.

The intensity of the combustion of fuel is directly dependent upon two factors—time and space. For example, the evolution of heat from a given amount of fuel in the shortest time and in the smallest space results in the hottest fire.

The subject of fuel combustion has been treated most narrowly because it has been customary to estimate the value of fuel from a thermal value standpoint; or in other words, heat was *heat* simply in all our calculations. Steam boiler practice has largely been to blame for this, owing to the ease of measuring results in that art.

I shall endeavor to make clear that conditions of combustion for steam generation are diametrically opposed to those experienced in the practice of almost any other art, and in de-

monstrating this, the fact will be brought out that the value of the fuel for use in other arts than steam generation is not properly to be calculated from the thermal value basis, as in steam generation.

The customary rating of fuels from a thermal value standpoint is, I believe, very largely responsible for the very narrow view of the study of combustion afforded us in existing records. Combustion heat has been utilized for countless ages, and probably because of its commonplaceness combustion is not as well understood to-day as wireless telegraphy. The great importance of fuel for steam generation and the ease of measuring results in that art is also responsible for the very narrow view previously taken of fuel and fuel values for combustion. The steam boiler furnace is used essentially for the production of sensible heat, which sensible heat is applied to water and by convection evenly distributed over any desired area. The energy of the fuel employed for steam generation must be in the form of temperature energy or sensible heat, and at the same time be held in the smallest volume of gas carrier possible, consistent with the attainment of complete combustion. In steam-practice combustion we have the simplest and most limited chapter in the broad study of combustion. This chapter may properly be entitled the generation and application of pre-generated heat. This is the old, well-known chapter which has heretofore been generally accepted as the whole book. It is not my desire to repeat history, and I will simply bring out for the sake of comparison a few of the points.

The standards of fuel appraisalment as established by calorimetric determinations, as aforesaid, measure only pre-generated or sensible heat. They are consequently misleading, narrow in scope and at the same time of little value in the other arts than steam generation, where combustion is most simply applied, that is, for the evolution of sensible heat.

There is much in the old axiom, familiar to us all in the form in which it has until recently been improperly stated, namely, that "Heat decreases in inverse proportion to the square of the distance from the seat of generation." This should be stated: "The power of a body to intercept heat is in inverse proportion to the square of the distance from the seat of generation."

A brief history of the conception of the Eldred Process may serve the purpose of making some points more clear. I wish especially to obviate the confusion which sometimes arises from the idea that the process is one for the conservation of waste heat; that the hot blast is the secret of its success, or that much combustible is returned and conserved from the escaping gases of the furnace operation.

As far as ten years back, I have noted and proved to my satisfaction in the study of combustion in connection with steam generation, that within reasonable limits a high furnace temperature produced a lower temperature of escaping gases than would a lower fire-box temperature. This I also determined by experiments to be due to the difference in volume of the gaseous heat-carrying body traversing the fire-box. A large amount of air in excess made a lower furnace temperature, and a large volume of gas carrier necessarily has to travel at such a rate to the stack that the water in the boiler would not have the same chance or opportunity to absorb the heat for useful evaporation that was afforded in the application of the same amount of heat in a small volume of gas carrier.

With this idea firmly fixed in my mind, I undertook, at the suggestion of a prominent lime manufacturing concern, to solve the problem of burning lime economically with coal fuel. My first attempt was to make what might be termed an economical fire for steam generating purposes—that is, a combustion of short duration. The conditions were ideal for such combustion; the furnace walls and the lime rock laying directly at the end of the furnace, absorbing the heat and reverberating this heat back on to the bed of fuel on the grate, causing a rapid destructive distillation. It was soon discovered that a high temperature was disastrous to lime burning, as the lime in the kiln was fused and cemented into almost a solid mass, and the disastrous effect of intense heat was plainly visible on the furnace walls. While the experimental kiln was being prepared for another demonstration, I observed the operating conditions of two similar kilns alongside. One was being operated with wood fuel, the other with a good grade of gas coal to which air was supplied by means of a steam blower. It was noted that one ton of this coal would afford a thermal value of 14,200 B. T. U. by testing in the Barrus Oxygen

Calorimeter, and that it would burn no more lime than a cord of wood under similar conditions, although the thermal value of the wood was slightly less than half that of the coal. Following up this clue in the endeavor to find the discrepancy apparent in the results obtained, the Eldred Process was conceived.

By analyzing the gases escaping from the two kilns it was quite evident that combustion was substantially complete. Neither was there any apparent difference in the temperature of these escaping gases, and the lime drawn from the kiln was also at the same temperature. To make the problem still more complex, it was found that the use of wood fuel would afford greater capacity than the coal fuel. From this it will be seen that the problem under consideration presented many difficulties, inasmuch as the results of actual practice did not bear out theory, that is, the theory based on results obtained in steam boiler practice. It became evident that the economical dissociation of the carbon dioxide from the lime rock was wholly dependent upon the proper application of heat at a certain temperature. I then demonstrated in the laboratory that 752° Fahr. were required to initiate the dissociation of carbon dioxide, and that in all probability 1200° Fahr. would suffice to completely transform a piece of lime rock of the actual size employed into calcium oxide or lime. The deduction from the experiment was that the heat derived from the combustion of the coal was practically all generated within the furnace before it came in contact with the rock within the kiln. By an electric pyrometer it was found that the furnace temperature was nearly $3,000^{\circ}$ Fahr. Thus it became evident that the relatively small amount of lime produced with coal was due to the fact that the heat absorbing power of the rock and lime was such that the portions lying near to the furnaces took up and stored very much more heat than was required for calcination, to the detriment of the rock above in the kilns, thereby greatly reducing the efficiency of the coal fuel as compared with wood, it being further understood that the first body of rock subjected to heat of the furnaces would be maintained at the temperature of the furnaces.

To accomplish my purpose of making economically a good lime from coal, I set about to produce a flame with this fuel

which would resemble a wood flame in duration and heat intensity.

In the body of lime rock under treatment there was sufficient heat to maintain the original ignition of the gaseous fuel from the distillation of the bituminous coal employed, and my object was to apply this in form of a heat producing agent and complete its combustion in immediate contact with the rock undergoing calcination, producing heat over a large area, getting its full value and obviating the difficulties before experienced, or, in other words, carrying into practice the old rule that the quantity of heat intercepted by any two like bodies of rock is inversely proportional to the squares of the distances from the seat of the generation of the heat.

The complete control of the regulation of the duration of combustion was accomplished by the use of neutral gases obtained from the kiln above the zone of combustion, to dilute the air supplied to the furnaces.

Instead of using the mechanical mixture of approximately 21% oxygen and 79% nitrogen ordinarily present in the atmosphere, I used enough diluent gas to give about the following proportions (An average of several analyses.):

Carbon dioxide	10.0%
Oxygen	14.6%
Nitrogen in air present	58.4%
Free nitrogen	17.0%

Owing to the fact that the oxygen in this gas mixture was much less in percentage amount than in the case of the normal atmosphere, the fuel body could be subjected to a strong forced draft which impelled the gases up into the kiln before combustion was completed, giving the desired result and at the same time allowing of the use of a forced draft under such conditions that the rate of combustion would be less rapid than with the ordinary natural draft and air. The presence of a larger volume of neutral gas carrier for the oxygen and the lower furnace temperature, presumably also decreased the rate of union of oxygen and combustible.

The CO_2 present in the draft supplied to the furnaces, also materially aided in the obtaining of the desired result by the splitting up of the gas as it passed through the fuel on the

grates, the heat absorbed by the endothermic reaction kept the furnaces down in temperature, lessening the rate of distillation to the desired degree.

Different fuels have been found especially applicable in different arts, but the scientific reasons for this fact seem to have been neglected to a remarkable degree by investigators. As illustrated in the limekiln experience before cited—the duration of the combustion of the fuel employed played the most important part in the obtaining of efficient results. Nature has provided numerous fuels which in combustion afford different velocities of combination or reaction, which means the duration of combustion, but she has supplied but one atmosphere to support combustion. The Eldred Process regulates the velocity of combination of the oxygen of the air with carbon by creating an artificial atmosphere low in oxygen, making it possible to use a strong forced draft and to utilize its mechanical force as a flame impeller. By proportioning the amount of diluent we may delay velocity of reaction to any desired degree, applying fuel value in the form of potential heat with the ultimate development of the sensible heat where it is to be used.

The comparative results of my first test will attest the value of the invention. The average coal consumed per barrel of lime on an output covering a year's run was shown to have been 73.4 pounds. The appreciation and application of these new principles during a week's continuous test showed an average coal consumption per barrel of 33.46 pounds.

A very good homely illustration of the economical results obtained by the application of the heating agent for the generation of heat where it is to be used, is found in the human body; where we know carbon is widely distributed and the oxygen carried in the blood to this carbon, the heat being generated over and throughout the entire body, the most wonderfully economic production of heat resulting in the operation. Consider what it would mean if the animal body had to be kept warm by the application of pre-generated heat applied to a hand or foot.

My process has been successfully applied to many branches of arts where comparatively low temperatures were required. The roasting of refractory ore mined in the Cripple Creek dis-

trict, showed better and more efficient work performed with 43% less coal of the same grade and from the same mine than was previously employed under forced draft conditions.

The Eldred Process involves a cyclic return of a portion of the waste gases, and this has led to speculation as to the effect such a cycle of travel has upon the constitution of the escaping gases. It has been thought by some that the use of diluent

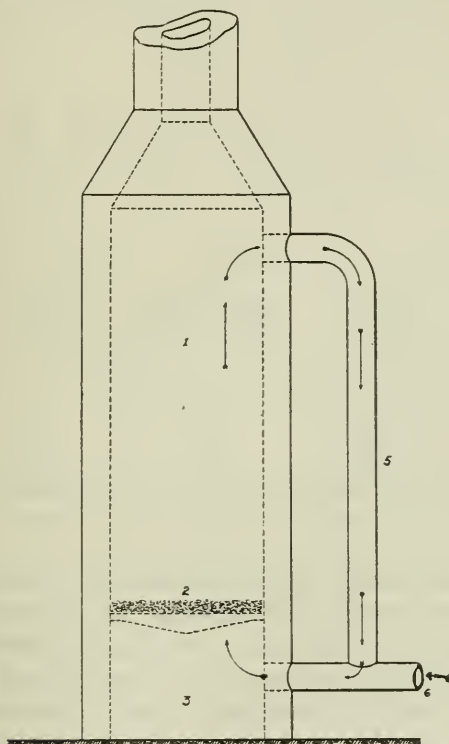


FIG. 1 GAS CYCLE

gas would increase the sensible heat losses at the stack. This is not the case. To illustrate the question involved in the so-called "gas-cycle," reference is made to Fig. 1. In this diagram 1 represents a chamber containing the material to be heated. A determined portion of the products of combustion is drawn out at the base of the stack and carried back uncooled through 5, to ashpit 3. A measured amount of air is admitted at 6. The gas and air mingle and pass through the grate and

fire-box 2. At the start the burned gases coming from the carbon fuel and passing up the stack normally contain nitrogen, 79%, oxygen, 15% and carbon dioxide, 6%. Suppose one part of these "normal" gases to be drawn back at the stack and to mix with four parts of air from 6, then the gas entering 3 will contain oxygen, 19.7% and carbon dioxide, 1.2%, the nitrogen, of course, remaining substantially unchanged. These pass through the fuel and, it is assumed, burn the same amount of carbon as represented by that in the "normal" gas, or the equivalent of 6% carbon dioxide.

The following table shows the progressive changes in the character of the entering and escaping gas. The nitrogen remains practically constant, namely, at 79%, so it need not enter into the calculations.

GAS DISCHARGED FROM STACK.			GAS-AIR MIXTURE ENTERING ASH-PIT	
Interval of time.	Oxygen. Per cent.	Carbon dioxide. Per cent.	Oxygen. Per cent.	Carbon dioxide. Per cent.
0	15	6		
1	13.7	7.2	19.7	1.2
2	13.5	7.4	19.5	1.4
3	13.4	7.5	19.4	1.5
The limiting values therefore approximate.				
	13.4	7.5	19.4	1.5

Or, in other words, the application of such a cyclic process, starting with stack gases carrying 6% of carbon dioxide and continuously diluting these with four volumes of air (calculated at the same temperature), would cause the percentage of carbon dioxide in the stack gases to increase to 7.5%, and the oxygen would be reduced to 13.4%, or the excess air expressed in percentage of that chemically combined would be reduced from about 250% to approximately 180% excess, a difference of 70%. In many furnaces of the reverberatory type 75% of the heat generated is carried away in escaping gases. Therefore, the reduction in the excess air by 70% would be equivalent to an increase in fuel efficiency of about 20%.

According to the theory of limits, equilibrium in this system is never attained, but actually it is quickly reached so far as can be shown by analysis of the gases at different points.

In calculating the gas-air mixture required per pound of coal, one has to take into consideration two factors. First, that less oxygen by volume is present than in ordinary air, and, secondly, that less excess oxygen actually is required with the Eldred Process. A slow, drawn-out combustion seems to require less oxygen for its completion than a rapid combustion.

The following formula serves for calculations. The cubic feet of gas-air mixture *A* required per pound of coal, allowing no excess is:

$$A = \frac{32 (T + 440)}{5\theta}$$

where *T* is the temperature in Fahrenheit and θ the oxygen content of the gas-air mixture entering the furnace.

In the application of the Eldred Process various forms of apparatus are employed.

A form of apparatus is shown in Fig. 2, as applied to a lime-kiln of the conventional type; *G* being a furnace communicating with a cupola *A* through an opening or arch. *J* and *K* are the fire and ash-pit openings, provided with suitable doors. A draft pipe or conduit connects at its upper end with *A*, through opening *C*, and at its lower end with the ash-pit *B*, through opening *E*, and has interposed in it a fan-blower *D*. That part of the conduit above the fan constitutes the suction pipe of said fan, and the part below the fan constitutes a delivery pipe therefor. A gate or valve *H* controls this delivery pipe. The fan has also an auxiliary outlet or delivery pipe *I*, controlled by a gate or valve through which a portion of the kiln gases may be disposed of without causing them to pass through the fire. At *F* the suction pipe is provided with an air inlet, also controlled by a valve. By adjusting this valve the relative proportion of air and kiln gases in the draft may be exactly controlled.

In conclusion, I may say that the ease of measuring the evaporation of water per unit of fuel or combustible employed, has distracted scientists from a full realization and clear understanding of what every practical furnace man employed in arts not dependent on evaporation of liquid masses fully appreciates—that it is erroneous to measure fuels by mere capacity to raise the temperature of water. There are almost countless

other applications of heat energy where no convection current exists to convey and equalize the energy imparted. Peculiar and hitherto unnoticed or at least uninvestigated discrepancies exist in the efficiency of different fuels for the same work under identical conditions. For example, I find as before stated, that one ton of coal used in an externally fired limekiln will do only about as much work as a cord of wood, yet the coal is of

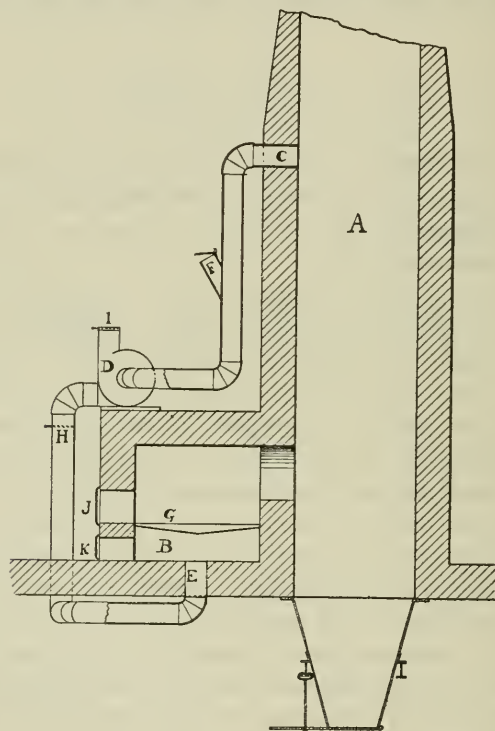


Fig. 2.

twice the theoretical thermal value. The lime burner can produce superior lime using wood fuel. He says: "Wood is the natural fuel for burning lime." Why? "Because it makes a flame of better quality than any other fuel commercially obtainable." The brick burner will tell the same story. The metallurgist wants a different quality of flame for varied branches of his art. Science has paid little or no attention to this intricate question heretofore. Nature's storehouse has

provided fuels of different flaming qualities, but unfortunately, her supplies are not replenished as rapidly as they are withdrawn, and wood, where needed most, has been exhausted and science has been striving for a remedy.

In the study of fuel natures and combustion we have many things to reason with that have been neglected heretofore. Time and space or duration and volume of chemical action must be most prominently reasoned with in combustion studies. Properly reckoned, fuel values must take into account—capacity of combustion obtained from union with oxygen, more especially with reference to duration or rapidity of union. The more rapid the union of oxygen with the combustible the more intense the heat evolved. I have classed this as the duration of combustion, and on the duration of combustion afforded by a fuel depends the adaptability for special work, and each bit of combustion work has a duration point of maximum efficiency. The heat evolved in a given time in a given space depends upon the duration of combustion afforded. In other words, from incomplete investigations made with somewhat crude apparatus, I have concluded that efficiency in combustion is dependent on heat wave lengths synchronous with the wave lengths of the material under treatment, and the heat wave length may be consistently regarded as directly dependent upon the duration of the combustion of the fuel used. Furthermore, I believe that we are too inclined to designate flames broadly under the heads of reducing oxidizing and neutral. The chemical effects of these flames are not realized to any great extent in a great many instances where they are respectively employed, and almost unconsciously flame regulation has heretofore been crudely practiced by regulating blast conditions and building light or heavy fires, as the case might demand, oxidizing or reducing flames. As an example of this, coal fired sheet-mill furnaces throughout the country employ heavy beds of fuel under forced draft for the purpose of pushing a long flame into the furnaces. Thus the flame length or duration of the combustion is maintained at the expense of the fuel.

We are inclined to explain problems too often by chemical theorizing. This problem presents a side which allows of a most simple and beautiful explanation. The explanation can

be found in the study of the difference between the indirect application of pre-generated heat to a solid body or fragmental mass and the direct application of a heat generating or producing agent to such a body or mass. There is so much food for thought and such wonderful results obtainable from the study of apparently so simple a subject, that one marvels that it has been heretofore totally neglected.

THE SEARCH FOR DIAMONDS.

Never before in the history of the United States has there been such a demand for diamonds as there was in 1905. Large quantities were imported, but the country produced none. In 1903 it produced diamonds to the value of \$50, in 1901 it had an output worth \$100, in 1900 its production was valued at \$150, and in 1899 the country boasted native diamonds to the value of \$300. Diamonds have been discovered in the United States in four different regions, but their actual place of origin is in every case unknown. All have been found in loose and superficial deposits, and all accidentally. It is not at all improbable, however, that some day the original sources of this queen of gems may be discovered.

The high price of diamonds has made the recent search for these precious stones in the United States and Canada keener than ever before. A careful watch for diamonds was kept during the examination by the United States Geological Survey of many samples of gold and platinum sands at the Lewis and Clark Exposition in Portland, Ore. A lookout for diamonds has also been kept by a number of persons who have been dredging for gold on an extensive scale in the rivers of California. In neither case have any finds been reported.

The occurrence of diamonds in the United States has been treated in some detail by Mr. George F. Kunz in a report which the Geological Survey will soon publish.

TOURMALINE AND TOPAZ IN SOUTHERN CALIFORNIA.

The southern counties of California bid fair to rival the Ural Mountains in the production of tourmaline, beryl, topaz, and the other precious stones which have been the pride of that region for the last half century. The Palo region in San Diego County has become especially notable in gem production, and Mr. George F. Kunz, of the United States Geological Survey, calls attention in his forthcoming report on the production of precious stones in 1905 to the fact that a number of adjacent localities give indication of yielding the same minerals.

Section of Physics and Chemistry.

Analytical Notes.BY SAMUEL S. SADTLER.

DETERMINATION OF THE HEAT OF COMBUSTION OF SOME COAL
BY THE PARR COLORIMETER.

In Parr's original article, which appeared in the *Journal of the American Chemical Society*, October, 1900, results of determinations made on Illinois coal were given, and comparisons made with the Mahler Bomb Calorimeter. In this article, the only charging material, with the exception of coal, is peroxide of sodium. Later with Lunge, it was stated that with hard coals (anthracite) a mixture of persulphate of ammonia and citric acid in definite amount, the heat contribution of which was found by a blank experiment, could be used to completely burn the carbon which would otherwise escape combustion with peroxide alone.

The writer believes that a better method of procedure, which does away with the blank determination, is to make the combustion with nothing but the coal and peroxide, and then to dissolve the product of the combustion reaction in a casserole with water, acidify with commercial muriatic acid and filter through a Gooch crucible prepared with an asbestos filtering layer. The piece of No. 10 wire used to start the reaction being picked out before filtering. If there is any heavy residue in the casserole, wash it several times with water and then with nitric acid (about 1-5) to dissolve any small particles of metal or oxide. The crucible is then dried to constant weight in an oven at 110°C., ignited and re-weighed. The difference is carbon. Multiply the weight found in grams by 2 (if half-

gram charge of coal was used) and then by 14,400 to convert into B. T. U. Add this result to that found in the calorimeter. Results will agree to about 50 B. T. U. if care is followed in the measurements of temperatures.

The writer feels that no matter how carefully the combustion is carried out, reliance in the results should not be had until the absence of a carbon residue was ascertained. The additional step of filtering and weighing up the residue is simpler and more certain than with the use of an exciting charge.

Successful results have not only been obtained with a wide range of coals, but the heat of combustion of samples of tar (water free), peat, and powdered cacao shells have been obtained. With crude oils, the writer has not been successful, due to the more volatile constituents rising to and condensing in the top of the combustion chamber, and thus escaping combustion.

SULPHUR IN OILS BY THE SAUER-MABERY METHOD.

The improved method here suggested is so simple, that it seems probable that a citation to the same effect might be found somewhere in the literature, but the writer has not seen such.

In the method described by Mabery, the air or oxygen is carried by a small tube within the main combustion tube to a constriction which is strongly heated, and at this point it meets the current of oil vapor mixed with a little air that is used to slowly drive it to this point, the oil being in a small boat under the air (oxygen) inlet tube and about half way from the ends of the tube to the constriction.

The improvement to be described, consists in only slightly drawing out the combustion tube at the center and putting a plug of platinized asbestos in this narrower portion. Instead of the oil vapor flashing through the tube, it burns quietly in the "contact" substance and the reaction can be readily watched at this point, as the vaporization and driving forward of the oil can be so regulated as to give a nearly steady glow. This must neither extend all the way to the other side of the plug, nor, until the reaction is practically over, fail to glow.

The writer has obtained quite satisfactory results on sulphur

oils, with this method, but prefers to use the special crucible described by him in the Jour. Amer. Chem. Soc., September, 1905, as he has found it useful for all sulphur-containing oils he had tried. The modified Mabery method is described, however, for the benefit of those who have only the facilities for carrying out the work by this method, and not by the "Inner Crucible" method.

USE OF MODIFIED COCHRAN FLASKS.

The flasks described by Cochran are for determining the percentage of fat in milk and milk foods, and are used similarly to the flasks or bottles used in the Babcock method. By heating, use of sulphuric acid and ether, the fat is collected without the use of a centrifuge. The writer had flasks* made, with the neck graduated with 100 divisions of larger bore, so that gas bubbles could rise to the top, and water and oil layers could separate.

This flask was designed for some other application than those suggested by Cochran, namely:

(1). The determination by volume of the non-saponifiable oil, in lubricating and similar oils.

(2). The approximate determination of naphtha in turpentine.

(3). The determination of the water in substances themselves soluble in heavy solvents, such as CHCl_3 , CCl_3 and CS_2 .

In the first of these cases, a considerable number of tests were made which were for the most part unfavorable, in that it did not seem to be even approximately accurate for some mixtures of mineral and animal oils, such as neatsfoot and lard oils, which seem to form the most troublesome emulsions. It may be possible to overcome the difficulty with the emulsions, and to get practically all the oil to rise in the graduated tube, but it is likely to be at such effort as to rob the method of any advantage as to quickness of operation. With some other oils, useful approximate results may be obtained.

The other two uses, which may be of only limited application, were successful.

The separation of naphtha may be carried out substantially

*Arthur R. Thomas & Co., Philadelphia, Pa.

as given in the U. S. Pharmacopœia, f. 236, described as follows:

"If 5 cc. of oil of turpentine be placed in a small beaker, and 20 cc. of sulphuric acid be gradually added, with agitation, while the beaker is cooled by immersion in cold water, and the contents, after cooling and renewed agitation, be transferred to a burette, graduated in tenths, the clear layer which forms after the dark mass has settled should not measure more than 0.35 cc. (absence of petroleum, benzin, kerosene, or similar hydrocarbons)."

After thorough cleaning with chromic and sulphuric acids, the flasks are filled with water, and then the oil under investigation is slowly dropped on the top of the small tube, the displaced water overflowing at the top of the larger tube. To counteract the lightness of the turpentine, the flask is tipped so that the position of the small graduated tube is raised compared with the larger tube. When the lower turpentine layer is brought down to zero and the upper layer is at or near to 100. A short length of rubber tubing, with a pinch cock, is then put on the larger tube and then the flask tilted until the layer of turpentine is brought down to the rubber. The flask is then righted. It still contains a little water, but when the mixing chamber is half filled with sulphuric acid, the water does not interfere with polymerizing of the sulphuric acid on the turpentine. The flask is cooled while the sulphuric acid is poured in, and while shaking, if much heat is developed. The acid is poured down the sides of the large tube in such a way that any little oil adhering to the sides is washed down. The flask is then filled with sulphuric acid until the mixture is brought just to the lower end of the graduated tube. After standing about an hour, the sulphuric acid is added to the larger tube, until the naphtha layers are both within the scale. The difference in the readings gives the approximate percentage of naphtha, by volume.

FOR THE DETERMINATION OF WATER IN SUBSTANCES SUCH AS
CAMPHOR.

For this determination the flask must be standardized. This may be effected by first filling with a heavy organic solvent

such as carbon disulphide or carbon tetrachloride. Then by carefully tipping the flask to depress the level of the solvent, water is dropped upon the surface of the solvent in the graduated tube. Six or eight drops will be sufficient for accurate reading in the tube, indeed, the accuracy of the standardization will be gauged by one's ability to measure the water that is run in. Weighing would be more accurate than the use of the burette.

The flasks made for the writer had a graduated tube of about $7/64$ inch inside diameter and with 100 divisions in a little over $3\frac{1}{2}$ inches. Each division is about $1/220$ c.c., or 100 divisions equal .45 c.c.

With a flask of this size, about 1.5 grams of crushed well-sampled camphor is used. If the sample contains 2% of water, the reading will be 4.4 or 44 divisions. If .4554 gram were taken, each ten divisions would correspond to 1% of water.

The weighed sample is introduced into the large tube, and washed down with a little light solvent, such as gasoline. The dirt then settles and then the flask is filled up with carbon tetrachloride, so that the water can rise in the small tube and be easily read off.

The writer offers the foregoing reference to the flasks, more in the light of suggestions than exact contributions to the literature. He believes, however, that workers will find that these and other uses for them will warrant their gradual introduction.

THE WORLD'S FAMOUS DIAMONDS.

The following list gives the weight of the world's most famous diamonds: Kohinoor, after second cutting, 106 carats; Loterie d'Angleterre, 49 carats; Nizam of Hyderabad, 279 carats; Orloff, 194 carats; Kohinoor, after first cutting, 279 carats; Regent of Pitt, 137 carats; Duke of Tuscany, 133 carats; Star of the South, 124 carats; Pole Star, 40 carats; Tiffany, yellow, 125 carats; Hope, blue, 44 carats; Sancy, 53 carats; Empress Eugenie, 51 carats; Shah, 86 carats; Nassak, 79 carats; Pascha of Egypt, 40 carats; Cullinan, 3025 carats; Excelsior Jagersfontein, 969 carats.

MME. CURIE has been nominated by the council of the University of Paris to succeed her husband, the late Prof. Curie, in the chair of General Physics held by him at the time of his death. The nomination has been accepted by the Minister of Public Instruction.

VANADIUM STEEL.

Willans & Robinson are now producing special vanadium steel alloys at the rate of 800 tons per annum at their Queensferry works, England. The ferro-vanadium used for the manufacture of these special alloys is obtained from the Llanelly works of the New Vanadium Alloys Company, in South Wales, and contains up to 30 per cent. of vanadium. The chrome-vanadium steels show the most remarkable properties. These contain from 10 to 20 per cent. vanadium. The vanadium steel industry is altogether an English industry; 80 per cent. of the production is taken by the motor car and motor omnibus manufacturers. In one case 150 axles of chrome-vanadium steel were ordered and are now running with satisfactory results, and a repeat order for 400 axles of the same alloy has been given. Chrome-vanadium steel has also been exported to France, although an import duty of £5 per ton has to be paid upon it.

The effect of vanadium upon ternary and quaternary steels is to increase the resistance to both static and dynamic tests. The highest test yet obtained from a chrome-vanadium steel, after special heat treatment, was a maximum breaking strain test of 193 tons per square inch; this steel showing at the same time great resistance to dynamic and torsional tests. This is a combination of properties which has never been obtained before, and is the peculiar feature of the chrome-vanadium steels. The nickel-vanadium steels are of great strength, but show much lower resistance to dynamic and torsional tests.—*Eng. and Mining Jour.*

TECHNICAL NOTES.

Care should be observed in placing direct-current motors where there is risk of gas; for the explosive may be ignited by spark or heat.

Not only does moisture in coal cause it to crumble on exposure to the air, but each per cent. of moisture present means 20 lbs. less fuel for each ton of coal. A coal that runs high in moisture, will usually break or crumble on exposure to air; this slacking being due to a loss of moisture from the composition of the coal.

The safest cable to use for direct-current work in the mines, is the concentric cable with double galvanized iron wire armoring, and for three-phase machines, the three-core cable with similar protection. Experience and careful observation have shown that the wear on a rope increases with the speed. It is therefore better, if more work is to be done, to increase the load and run at the same speed, than to carry the same load at a greater speed.

In the conveyance of compressed air, it should be remembered that the efficiency is diminished practically as the diameter of the pipes is decreased, which means, of course, that the pipes should be as large as conveniently practicable, with commodious receivers adjoining the air compressors.

The fixed carbon of a coal will not evaporate as much water as an equal weight of volatile combustible matter when properly fired; however, in practice, so much of the latter is lost that in determining the steam value of a coal, we may assume the carbon to be the only useful constituent.—*Eng. and Min. Jour.*

(*Stated Meeting, held Thursday, March 29th, 1906.*)

Fluorescence and Phosphorescence.

BY EDWARD L. NICHOLS.

The wierd shining in the dark of certain bodies ; the gleam of sea water when disturbed and other allied phenomena must have been known from the earliest times. When phosphorus was discovered, in the 17th century, the property which it possesses of glowing with a greenish light attracted universal wonder, and from that time the name of phosphorescence was given to all cases of the emission of light by bodies at ordinary temperatures.

At first it was imagined that the presence of phosphorus was indicated wherever phosphorescence occurred or perhaps that there was a group of allied bodies to which the phenomenon was ascribed. When, for example, in 1676, Picard noticed that upon shaking the mercury in a barometer in the dark there was a glow from the vacuum in the top of the tube he assigned it to the presence of a mercurial phosphorus. Hauksbee, one of the best known electricians of that period, studied this phenomena at considerable length, and he showed himself a true forerunner of the electricians of our day, who would have us believe that all physics is but a branch of electricity, by assigning to the phosphorescence of the barometer tube an electrical origin.

There are two distinct kinds of phosphorescence, the phosphorescence of vital organisms ; of glow worms, fire flies, jelly fish and the animalculæ that cause sea water to shine at night, and the phosphorescence of matter not imbued with life. The presence of light always indicates radiation and radiation is a process involving the expenditure of energy. In the case of living organisms the energy thus expended may have its origin

in the vital processes since an animal is a machine consuming fuel and transforming the energy thus obtained into various forms. In other cases radiation is due to motions of the particles of a body derived from energy received from without or to setting free of energy stored when the body was formed. The usual type of visible radiation, known as *incandescence*, is common to all bodies when heated above a certain temperature, the red heat. It is a definite function of the temperature and is produced by one stimulus only,—heat, which sets up the necessary motions of the particles. The emission of luminous radiation due to any other stimulus is termed *luminescence*. It may occur at any temperature; has been observed even in the case of bodies cooled by liquid air*, and is known to accompany the incandescence of certain oxides, modifying the light of freshly ignited CaO, ZnO, etc.† It is variously known, according to the stimulus which produces it, as:—

Photo-luminescence, produced by the action of light.

Tribo-luminescence, produced by friction.

Piezo-luminescence, produced by pressure.

Crystallo-luminescence, produced by the process of crystallization.

Chemi-luminescence, produced by chemical action.

Electro-luminescence, produced by electrical action.

Cathodo-luminescence, produced by the action of cathode rays.

Radio-luminescence, produced by the action of obscure rays from the radio-active elements.

X-ray-luminescence, produced by the action of Roentgen rays.

Thermo-luminescence, produced by sudden changes of temperature.

Luminescence of a body observed during the time that the stimulus acts is called *fluorescence*. When the emission of light continues after the stimulus has ceased the phenomenon is called *phosphorescence*.

Why in many cases the luminescence of a substance ceases with the excitation or so soon thereafter as to be observable

*See Dewar: Proc. Royal Soc. (5) p. 340.

†Nichols and Snow: Phil. Mag. (5) Vol. XXXIII, p. 19.

only by means of the phosphoroscope while in other instances the effect may last for minutes, hours, or even months is not as yet definitely known. Liquids are fluorescent but never phosphorescent and the fluorescence of liquids is believed to be dependent upon the dissociation of a dissolved substance. It has indeed been shown by Buckingham* that the fluorescence of electrolytes increases in a definite manner with the dissociation.

In solids luminescence is supposed to occur only where the constitution is that of a solid solution and to be due to the presence in solution of traces of certain elements, such as copper, chromium, manganese, nickel, cobalt, lead and certain of the rare metals, such as cerium, lanthanum, yttrium, erbium, etc. The solvent may be a sulphide, such as CaS , which is used in the preparation of Balmain's paint, or ZnS , as in Sidot blende; a fluoride, such as CaF_2 , or fluorspar (from the luminescence of certain specimens of which as studied by Stokes the name fluorescence is derived); a silicate, as in willemite, etc.

The difference in the behavior of specimens of the same substance as regards the duration of the effect is very striking. One of two specimens of willemite, for example, the fluorescence of which when excited by the light from a spark-gap with iron terminals exhibit the same brilliant green color will continue to glow for many minutes after the cessation of the stimulus while the light from the other disappears at once.

The character of the spectrum of luminescent substances differs from that of an incandescent body in several important respects. Both classes of spectra are continuous, but the range of the wave lengths represented in incandescence is far greater than in luminescence. In the case of incandescence the maximum of intensity, for any temperature which can be artificially produced, lies in the infra-red and the position of the maximum moves progressively from longer to shorter wave lengths through the spectrum in accordance with a definite law as the temperature rises.

In the case of luminescent bodies the maximum of intensity, so far as known, is always within the visible spectrum or in a few instances, possibly, in the ultra-violet, and its position is

*Buckingham: *Zeitschrift für Physikalische Chemie*, Vol. 14, p. 129.

fixed as to wave length for a given substance and *independent of the intensity of excitation and of the character of the stimulus.**

Fig. 1 affords a comparison between the energy curve of the spectrum of incandescent carbon at 1600° C. and that of the luminescence of fluorescein. In the former only the small part of the energy which is represented by the area enclosed by that portion of the curve which lies between the limits of the visible spectrum, V and R, is light-producing, whereas the entire spectrum of luminescence is comprised within those limits. The maximum of the incandescence spectrum is situated at about 1.47μ , that of the luminescent spectrum at 0.52μ . Drawn in this way the curve for luminescence appears to indi-

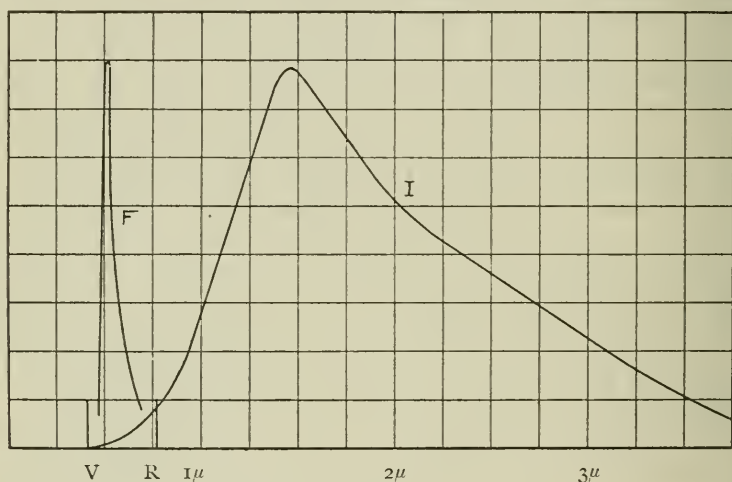


Fig. 1

cate a narrow band, almost a line; but if we increase the scale of wave lengths twenty-fold, as in Fig. 2, we find the type of the luminescence curve to be very similar to the energy curve for incandescence. Each is characterized by a single sharply defined maximum and by a steeper slope towards the violet than on the side towards the longer wave-lengths.

This resemblance is by no means confined to this particular case. The curves for the following substances are of the same type† and it is probably common to all luminescence spectra of solids and liquids.

*Nichols and Merritt: Physical Review, Vol. XIX, p. 18.

†Nichols and Merritt: Physical Review, Vol. XVIII, p. 403; XIX, p. 18; XXI, p. 247.

FLUORESCENCE SPECTRA.

Fluorescein (in alcohol).
 Eosin "
 Naphthalin-roth "
 Rhodamin "
 Resorcin-blau "
 Quinine Sulphate (in water).
 Chlorophyll (in alcohol).
 Aesculin (in water).
 Canary Glass.
 Sidot blende.

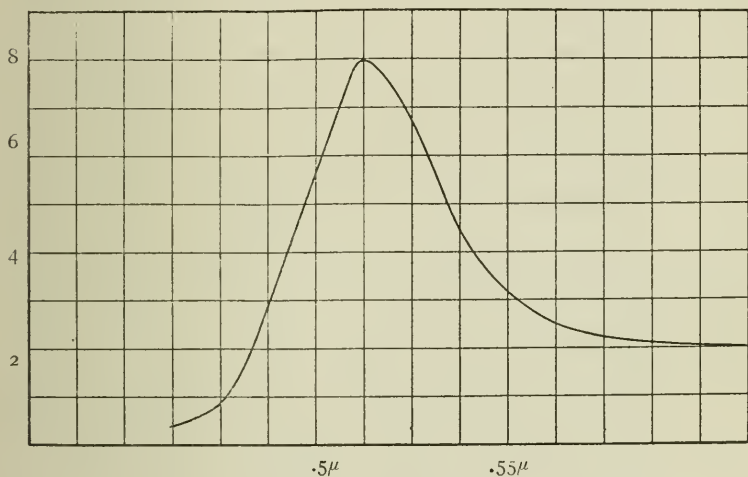


Fig. 2

PHOSPHORESCENCE SPECTRA.

Cuban fire fly (measured by Langley).*

Numerous inorganic phosphorescent substances studied by Lenard and Klatt.†

The intensity of luminescence is always far too small to admit of the determination of the distribution of energy in the spectrum by direct measurement, but it is possible by means of the spectro-photometer to compare many such spectra with the spectrum of such source as the acteylene flame, the energy curve

*Langley and Very: Phil. Magazine (5) XXX, p. 200.

†Lenard and Klatt: Drude's Annalen (15) pp. 225, 425, 633.

of which is known, and thus to be obtained the curve for the distribution of energy in the spectrum of the luminescent body. It is in this indirect way that the curves shown in Figs. 1 and 2 were determined. By using monochromatic light of various wave lengths for excitation we find that rays corresponding in wave length to the regions of absorption of the substance act as a stimulus whenever the wave length of the absorption band is less than that of the luminescent spectrum, and that absorbed light of greater wave lengths is inactive.

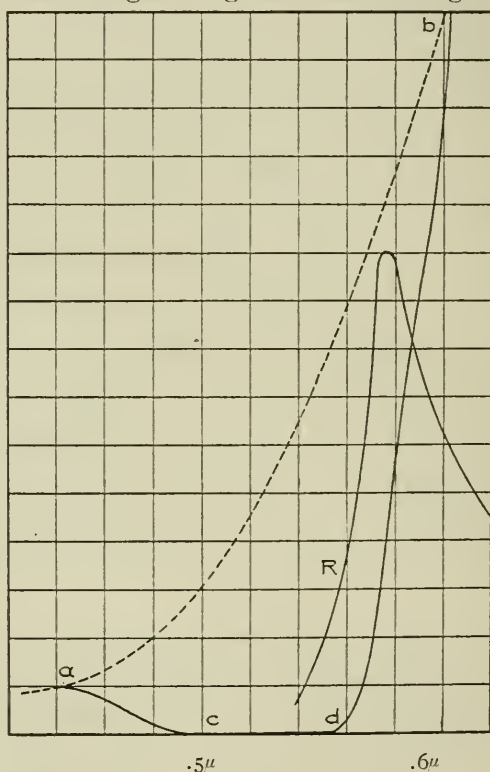


Fig. 3

The position of the spectrum of luminescence is determined by that of some absorption band nearly or not coincident with the luminescence spectrum, the maximum of the absorption band always lying slightly further towards the violet.

In Fig. 3, for example, the dotted line *ab*, is the energy curve of that part of the spectrum of an acetylene flame which

is included in the diagram. If a cell containing a certain solution of rhodamin be interposed in the path of the light from the flame we get the energy curve, *acdb*, for the transmitted light. In other words, the solution, which is nearly transparent at *a* and at *b* becomes nearly opaque from *c* to *d* and the figure depicts an absorption band of this solution having a maximum (or minimum transmission) between *c* and *d*. Associated with this band is the fluorescence spectrum of rhodamin, the energy curve of which is shown (curve R). The maximum of fluorescence lies at 0.577μ towards the red from the maximum of absorption.

In all the cases studied the absorption band and the luminescence spectrum overlap and all the wave lengths included in the absorption band are capable of producing ecitation. Since the luminescence spectrum is independent of the character of the exciting light, the longest waves that may be used for excitation will produce a fluorescence spectrum, some of the wave lengths of which are shorter than the wave length of the light used as a stimulus. The law of Stokes, who thought from his observations upon fluorite and some other substances, that the exciting light never exceeded in wave length the fluorescence which it was capable of producing, is not strictly true.

Many of the phenomena observed in the study of phosphorescence would lead one at first to suppose that the relation between phosphorescence and fluorescence could not be the simple one stated in a previous paragraph. In many instances the color of phosphorescence is seen to change as the light dies away. In other cases the fluorescence of a substance will present one color, and the phosphorescence, another. When, for example, Sidot blende is excited by means of ultraviolet light or by the ex-rays it exhibits a fine blue fluorescence which upon cessation of excitation changes to a green phosphorescence.* These phenomena are, however, capable of explanation from the fact established by Lenard and Klatt† and others that many substances have luminescence spectra containing two or more bands. It is probable that each band in such luminescence spectra is due to the presence in solution of a

*Nichols and Merritt: Physical Review, Vol. XXI, p. 247.

†Lenard and Klatt: l. c.

given metal. Where only one metal is dissolved we have a fluorescence spectrum consisting of a single band. Where two or more metals are present each one may produce independently its own band giving a complex spectrum.

The rate of decadence of these bands, after excitation ceases, varies greatly and the color of phosphorescence therefore changes as the light dies away. In certain cases decay is so rapid that it is not possible to observe a color which is prominent in the fluorescence of the substance for any appreciable time after excitation has been interrupted. Since moreover each band is associated with a particular absorption band the fluorescence may vary greatly with the stimulus. In Sidot blende, the fluorescence spectrum of which consists of a brilliant green band and of one or more bands in the violet, we may produce a green fluorescence by the use of light in which the visible rays predominate, or blue fluorescence, by means of an ultraviolet stimulus or by the use of X-rays. Such stimuli excite the violet bands so powerfully that they dominate in the production of the color or fluorescence, but as soon as excitation ceases the violet component disappears, on account of its exceedingly rapid decadence, and the phosphorescent light, which persists, is green in color. The varying rate of decay of two bands may likewise serve to explain the change of color of phosphorescence as the effect dies away. The more fleeting of two bands may be the stronger, immediately after the cessation of excitation but its domination over the color-tone of the light disappears with its decadence and the color goes over by insensible gradations to that characteristic of the other band, which although weak at first is more persistent.

There is another cause for apparent changes of color which affects all phosphorescence,—the transition to the faint gray which follows any color sensation whatever as the intensity becomes too feeble to stimulate color vision. The rods of the retina according to the physiologists continue to be excited by these weaker rays and this sensation, which is independent of the wave length of the stimulus, is ill-defined colorless gray sometimes designated by the term *rod white*. This is the final retinal sensation received from the light of phosphorescence before extinction.

The law of the decadence with the time was carefully in-

vestigated by E. Becquerel, to whom our first systematic studies of phosphorescence are due. Becquerel found his observations to be approximately expressed by the exponential equation

$$I=I_0e^{at}$$

but subsequent measurements have shown that the decadence does not follow this simple law and several attempts have been made to find an empirical equation which will represent the observed results. It is evident that in the case of substances having several bands in the phosphorescence spectrum, each of which differs in its ray of decay, the law of decadence for the light as a whole will be a complicated one. Since, however, as has been shown, by Professor Merritt and the present writer*, the various wave lengths of a single band decay at the same rate, it should be possible from observations upon the light of such a band to determine the law.

The phosphorescence of Sidot blende affords favorable conditions for the study of these phenomena since the violet bands are of very short duration while the brilliant phosphorescence of the green band is persistent. In some recent experiments on this substance it was found possible to observe a given wave length of the green phosphorescence band by means of the spectrophotometer and to record its intensity as a function of the time. The observations covered an interval of about twenty seconds from the cessation of excitation.

A study of the curves thus obtained showed that the decay of intensity was not exponential. If, however, we adopt the theory that the exciting light serves to dissociate the molecules of the luminescent substance, breaking them up into two electrically charged particles, and that luminescence is due to the recombination of these separated ions; and if we assume that the law of recombination is the same as that for ions in a gas; it is possible to derive an expression for the intensity of the light due to the collisions between the positive and negative ions. If the number of positive ions present in a unit of volume at any time be t and the number of collisions between a position and a negative particle be proportional to the number

*Nichols and Merritt.

of each present; and if, finally, a certain proportion of the collisions produce a recombination of the ions with emission of light; we have

$$I = \frac{I_0}{(a + bt)^2}$$

where a and b are constants. The intensity I according to this hypothesis should be inversely proportional to the square of the time and a curve having times as abscissae and the reciprocal of the square root of the intensities as ordinates should be a straight line. Our observations thus plotted were found to be

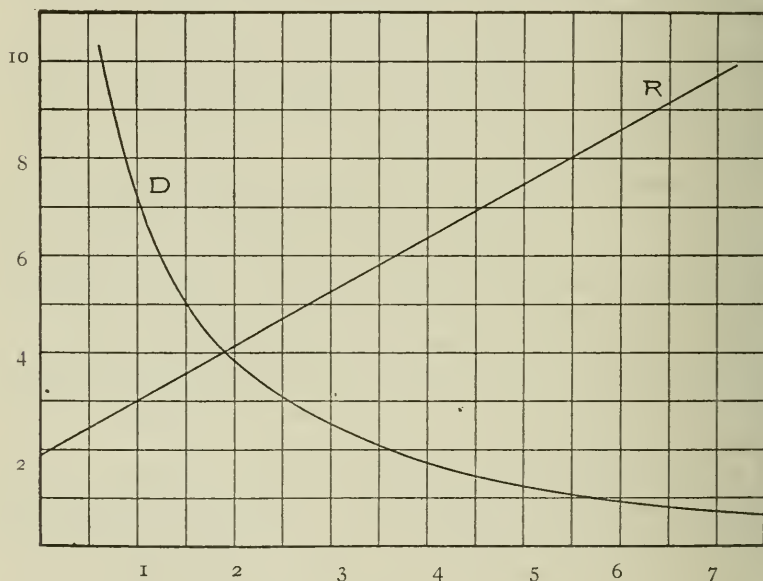


Fig. 4

in conformity with this hypothesis within the area of observation. In Fig. 4 one of these decadence curves (D) and the line of the reciprocals (R) is shown.

Knowing that the law of decadence for the various wave lengths of the green band is the same we then substituted for the spectrophotometer a Lummer-Brodhun photometer, one side of the screen of which was coated with Sidot blende. The photometer carriage was mounted in a fixed position at one end of a long photometer bar and a standard light of suitable

intensity, consisting of an acetylene flame carefully screened and viewed through an aperture five mm. in diameter, was so mounted that it could be shifted to any desired position upon the bar.

A mercury arc lamp of the Lummer type served as an exciting source. The light from the mercury arc was passed through a color screen opaque to the green and yellow lines so that the exciting light consisted of those portions of the violet and ultra-violet spectrum capable of transmission through glass.

It was possible by this method to extend observations of the decadence curve of phosphorescence over the period of fifteen

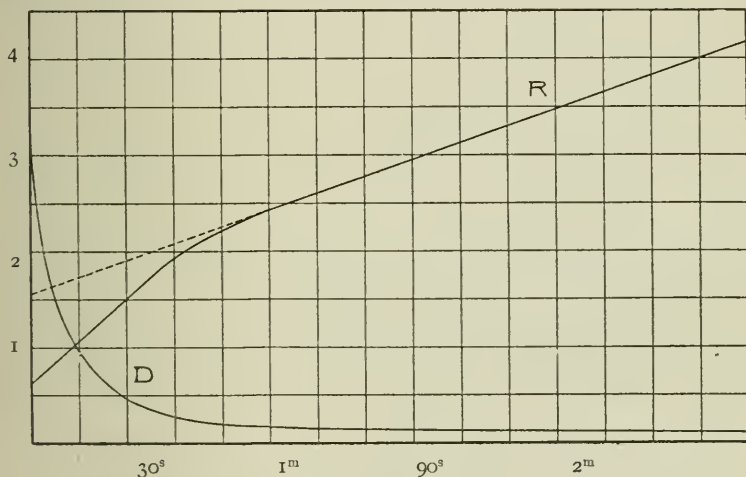


Fig. 5

or twenty minutes or nearly 100 times as long as in the observation of monochromatic light with the spectrophotometer. The curves thus obtained, which were plotted in the manner already described with the square root of the intensities as ordinates, exhibited a new and unexpected feature. Starting from the intercept the curves as before were straight for about ten seconds. They then turned more or less sharply downward, after which they again assumed the form of a straight line, but of different slope. It would appear therefore that in the decadence of the phosphorescence of this substance a rapid rate of decay is followed by another and slower decadence, both of which follow the law that the intensity is inversely pro-

portional to the square of the time. Fig. 5 shows a typical decadence curve (D) and the corresponding curve (R) for the reciprocal of the square root of the intensity. The diagram covers an interval of only two and a-half minutes. It refers to observations made after exposure of the Sidot blende screen for two minutes to the violet rays of the mercury lamp.

Experiments upon the decadence of the light emitted by a specimen of phosphorescent willenite gave results similar to those obtained with Sidot blende. The exciting source in these experiments was an electric spark between iron terminals and the luminescence immediately after the cessation of the spark discharge was quite as bright as in the case of the Sidot blende. Decadence was, however, much more rapid; the interval during which measurements could be made extending only for about one minute. The curve for the reciprocal of the square root of the intensity as a function of the time consists as before of two straight lines varying in slope. Similar results were obtained with Balmain paint and with a phosphorescent substance of unknown composition imported from Germany—the so-called *Emanations Körper* used in the study of radioactivity. Since many of the observations on the decay of phosphorescence made by Becquerel, when tested by plotting the reciprocal of the square roots, show the same character, it is probable that this is the general law of decadence for all substances.

The initial intensity of phosphorescence and the duration of the effect increase as the time during which a substance is exposed to light increases and continued exposure leads to a saturation such that further excitation is without effect. In Fig. 6 the initial phosphorescence of Sidot blende as function of the duration of exposure to the light of the mercury arc is shown. Complete saturation is not attained within the time limit of the diagram but the approach to it is obvious. The curve also exhibits the same in which the fluorescence of this substance gradually increases during excitation. There is during this period a storage of energy by the freeing of ions and these recombining after exposure give us the phosphorescence. The decadence curve is, however, not the counterpart of the curve for the growth of luminescence but the two related to one another in a manner curiously like that of the curve for the

rise of induced electromotive force in an electric circuit and the decadence of e. m. f. when the circuit is broken. Compare in this direction Fig. 6 and curve D in Fig. 5.

The effect of excitation upon the luminescent substance is to produce a curious instability which may be likened to that of iron subjected to the action of the magnetic field. If Sidot blende which has rested for several days in the dark be exposed to light for a time inadequate to saturation, say ten seconds, the decadence curve will have the form of Curve 1 Fig. 7. If it then be saturated the decadence observed will be represented by Curve 2. If, now, it be exposed again, for the same interval of time as in the first instance, the decadence will be much slower in consequence of the previous saturation. (See curve

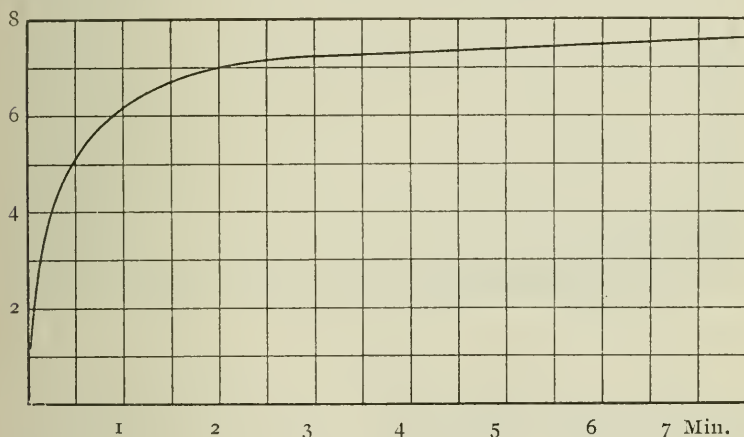


Fig. 6

3.) There is a certain retentiveness of luminescence and the effect of previous excitation to saturation shows itself for several hours. If, for example, the short excitation after saturation be delayed for several hours the substance will have drifted back into a condition more nearly like that in which it was after being in the dark for several days, but yet it will not have returned completely to the state attained after prolonged rest. As in the case of iron which has been magnetized and which loses its residual magnetism with time, a phosphorescent substance does not return to complete neutrality in accordance with any regular law. That is to say its condition even after

three or four days is not always the same. Other influences besides that of time appear to affect the state of the substance. Five minutes' subjection to a temperature of 100° C. will, for example, have more effect than several hours of darkness. Red and certain intra-red rays are still more effective. Light from an incandescent lamp after passing through ruby glass will in a few seconds change the condition of Sidot blende in such a manner that the decadence after ten seconds' exposure is much more rapid than is the case when the exposure is made after prolonged rest. (See Curve 4 of Fig. 7.) Whether rest in the dark would ever bring the substance into the condition to which it comes within a few seconds under the influence of red light has not yet been determined. These effects are better

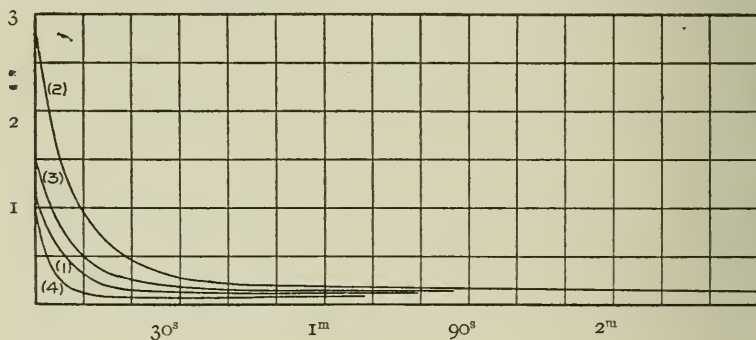


Fig. 7

seen in Fig. 8, in which the reciprocal of the square roots of these observations are plotted.

The phenomenon of retentiveness may be clearly exhibited by exposing a screen to red and then measuring the decadence after successive exposures to exciting light, each exposure being greater than the foregoing until saturation is reached after which a similar series of exposures each shorter than the foregoing are made. The curves for these shorter exposures after saturation do not correspond as to duration on account of the retentiveness of the substance and if a curve be plotted taking the reciprocal of the square root of the intensity in each case after a given interval of time, say three seconds, from the cessation of exposure with length of exposure as abscissæ, we get a curve analogous to a hysteresis curve for iron. (See Fig. 9.) The same phenomena as regards saturation, and retentiveness

are observed in the case of willemite, but the phenomena are less marked.

The effect of red and infra-red rays upon phosphorescence was first observed by Thomas Seebeck, the discoverer of thermo-electricity, whose observations were described by Goethe* in his *Farbenlehre*. E. Becquerel† and later his son, H. Becquerel‡ made an extended study of this subject and the latter used screens of phosphorescent material for the purpose of mapping the infra-red spectrum of the sun. J. W. Draper§

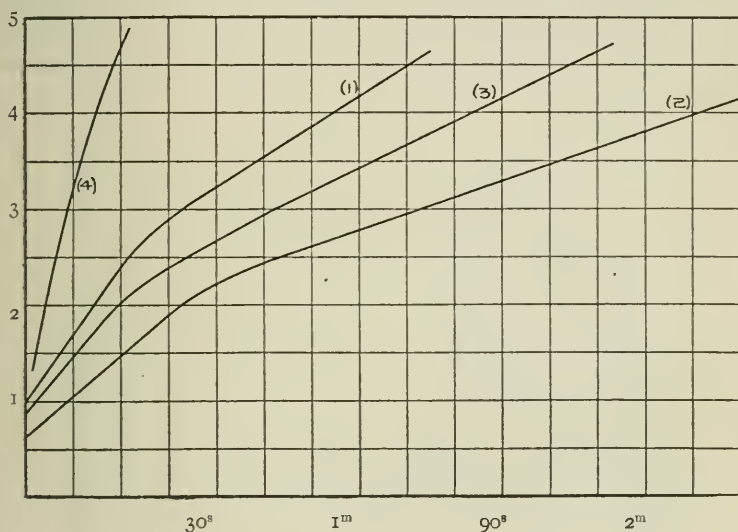


Fig. 8

in 1881 photographed the effect by submitting screens first to the action of the infra-red spectrum after which a contact photograph from the surface was taken. Fomm¶ made careful studies of the sun's spectrum by this method.

In 1904, Dahms|| studied the effect of different parts of the spectrum upon previously excited phosphorescent surfaces, such as Balmain's paint, strontium sulphide with copper, zinc

*Goethe: *Zur Farbenlehre* III, page 55.

†E. Becquerel: *Comptes Rendus* 14, p. 903; 77, p. 30; 83, p. 243; also *La Lumière*, Vol. I, p. 32.

‡H. Becquerel: *Ann. de Chim et Phys.* (5) 30, p. 1.

§Draper, J. W.: *Phil. Mag.* (5), Vol. II, p. 160.

¶Fomm: *Wied. Ann.* 40, p., 681.

|| Dahms: *Drude's Ann.*, 13, p. 425.

sulphide, and fluorspar. He found the action to be selective, not all wave lengths of the infra-red having the power to darken the phosphorescent surface. His photographs show an active region in the infra-red, followed in the case of Balmain's paint and zinc sulphide by a narrow inactive region. From the side towards the violet of this inactive band all wave lengths are effective in reducing the brightness of the surface until that portion of the spectrum is reached which is capable of producing phosphorescence. In certain cases, particularly that of Balmain paint, a limited group of rays in the extreme violet were likewise found to have the power to darken the surface.

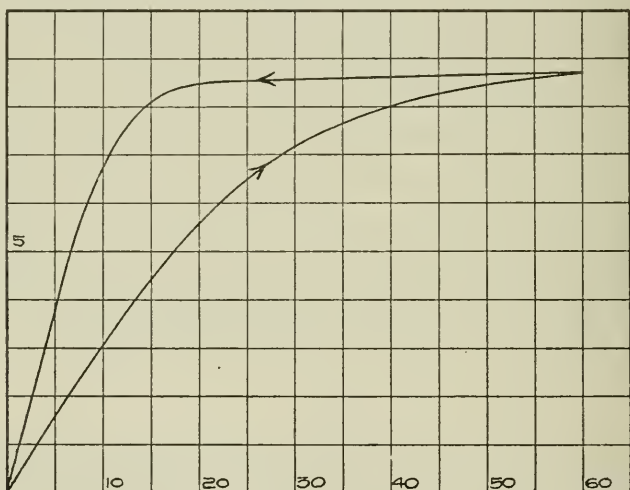


Fig. 9

Sidot blende is more strongly affected than other phosphorescent substances thus far studied, and it is easy by throwing upon a screen of this material, previously excited to phosphorescence, the spectrum from a source of light, such as the electric arc, to observe the phenomenon.

The calibration of Dahm's instrument did not extend to the infra-red and for the purpose of checking his results and of obtaining more definite information concerning the effect of this portion of the spectrum upon Sidot blende, Professor Merritt and the present writer have recently made measurements with the spectrophotometer upon the luminescent spectrum of this

substance; comparing the brightness of the same when exposed to a given wave length of radiation from a Nernst filament, with the intensity of luminescence when not thus exposed. For this purpose a mirror spectrometer was set up with quartz prism and monochromatic rays varying in wave length from $.8\mu$ to 1.6μ were thrown upon the luminescent surface under observation. The effect became easily measurable at wave length $.8\mu$ which even for this weak spectrum reduced the intensity of luminescence by 5%. It rose rapidly to a maximum at $.9\mu$ which was found to be the most active portion of the infra-red spectrum. The inactive band was located

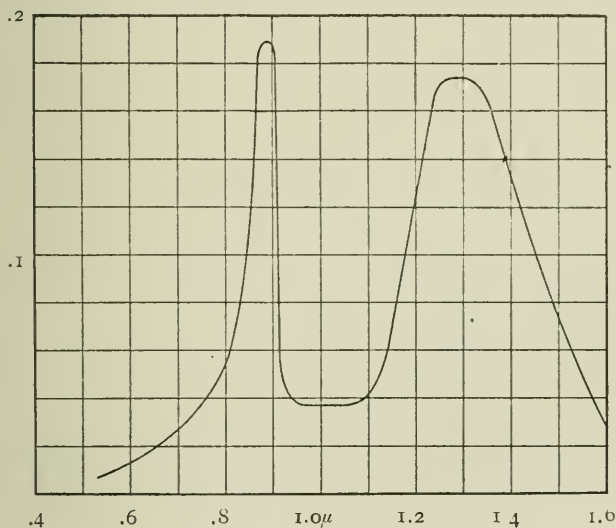


Fig. 10

as lying between $.93\mu$ and 1.1μ , beyond which lies a second active region at 1.3μ . The results are shown graphically in Fig. 10.

When infra-red light is thrown upon a phosphorescent surface after excitation has ceased the effect manifests itself by an immediate change in the rate of decay. Upon the cessation of exposure to these rays the phosphorescent surface immediately returns to its original decadence, no after-effect of such exposure being apparent. Fig. 11 shows the decadence of a sidot blende screen excited to saturation, then allowed to de-

cay under normal conditions, 13 sec., at which time the light from an incandescent lamp behind ruby glass was thrown upon the screen for a few seconds then removed and then thrown upon the screen again. The effect is best shown in the curve for the reciprocal of the square root of the intensities (*a, b, c, d, e.*) The curve *a, b, f,* is the ordinary decadence curve.

Of the influence of temperature upon luminescence our knowledge is as yet fragmentary. We know in a general way that numerous organic substances such as paraffine, stearine, albumin and ethyl alcohol, which are not appreciably luminescent at ordinary temperatures, become so when cooled to

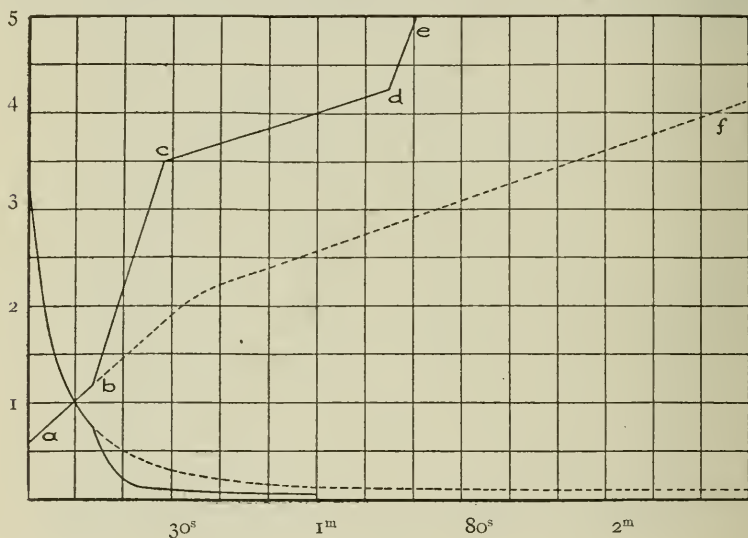


Fig. 11

about -190°C . The most striking experiments of this description, which was devised by Dewar, consists in cooling an egg in liquid air, breaking it open and exposing the albumin to the light of the electric arc. The blue glow which surrounds the yolk is very brilliant and remains visible in the dark for several minutes. The yolk shows no luminescence.

Other forms of albumen were tested in the course of an investigation of the luminescence of organic substances at the temperature of liquid air*. These showed only a feeble yel-

*Nichols and Merritt: Physical Review, 18, p. 355.

low phosphoresce instead of the fine blue of the white of egg. It is probable that the luminescence of the latter substance is due to traces of some dissolved metal; the albumin being merely the solvent.

Certain substances such as phthalic anhydride, anti-pyrin, salicylic acid, arsenious oxide, and benzoic acid show their most intense phosphorescence at temperatures somewhat above -190°C^* .

Many phosphorescent substances, after exposure to light, glow for a time when suddenly heated. This phenomenon, *thermo-luminescence*, appears to be due to an unlocking of previously stored energy by heat. That there is no transfer of heat energy into the energy of luminescence is probable since the effect is temporary and since the glow cannot be obtained by subsequent heatings unless the substance be first subjected to its proper stimulus.

In this paper many aspects of the subject have been altogether ignored. To the extensive researches of Lenard and Klatt, who determined the type of phosphorescence produced by the solution of various metallic salts in a variety of solid solvents only the briefest reference has been made. The effect of fluorescence upon the absorption of light by the fluorescing substance, discovered by Burke† for canary glass and subsequently confirmed in the case of various organic liquids‡, has not been considered nor has anything been said about the related phenomenon of the increase in electrolytic conductivity of solutions when excited to fluorescence§. Both effects, although experimentally established by the investigators cited, have since been sought for by Carmichael§ without success.

Other recent investigations, the discussion of which is beyond the limits, as to space, of the present paper, are those of Morse||, who has shown that in addition to the usual continuous fluorescence spectrum certain specimens of fluorite under powerful illumination have well defined line spectra of fluorescence.

*Nichols and Merritt: l. c.

†Burke: Phil. Trans. 191 (A) p. 87; Proc. Royal Soc., 30 III, 1905.

‡Nichols and Merritt: Physical Review, XIX p. 396.

§See Nichols and Merritt: l. c.

||Morse: Astrophysical Journal, 21, p. 83.

Radiation of this character from solids is altogether foreign to previous experience and no adequate explanation has as yet been found unless indeed the suggestion put forward by the author be substantiated, that the spectra have their origin in gases occluded within the crystals. This view finds support in the very remarkable fluorescence spectrum of sodium vapor described by Wood* who has obtained, by varying the conditions of the experiment, in place of the fluorescence spectrum first observed by Wiedemann† a line spectrum of great complexity.

In luminescence we have one of the most important branches of the science of radiation. For many ears it has been one of the most neglected branches of that science. Our knowledge of the phenomena is far complete and no satisfactory theory has as yet been established. The older and simpler views of the constitution of matter were indeed inadequate for such speculations and it was impossible to form any definite conception of a plausible mechanism to account for the observed facts. With the new hypotheses of matter already developed to account for the phenomena of solution, electrolysis, dissociation and radioactivity at our service this difficulty no longer exists. We can now imagine various intramolecular processes to account for isolated facts and even groups of facts of luminescence and suggestions looking to a theory have been formulated by Wiedemann and Schmidt, Voigt and others. A vast amount of quantitative work, however, remains to be done before anything like a complete theory is likely to be presented, or if presented can possibly be confirmed in all its details. Theory building in such a field as this will inevitably lead physicists to further insight into the nature of matter and thus ultimately to practical applications in a department of physics which at present appears to be of purely scientific interest.

Physical Laboratory of Cornell University, March, 1906.

*Wood: *Phil. Magazine* (6) 6 p. 362.

†Wiedemann: *Wiedemann's Annalen*, 57, p. 447.

THE PRODUCTION OF FLUORSPAR IN 1905.

The total production of fluorspar in 1905, as reported by Mr. Edmund Otis Hovey, of the United States Geological Survey, was 57,385 short tons, valued at \$362,488, most of which came from the mines in Illinois and Kentucky. This is an increase of 20,933 short tons in quantity and of \$127,733 in value, as compared with 36,452 short tons, valued at \$234,755, in 1904. The production, furthermore, is greater than ever before, surpassing the previous record year, 1902, by 9367 short tons in quantity and \$90,656 in value. The companies report such active demand for fluorspar, particularly for use in open-hearth steel furnaces, that the production of 1906 is likely to exceed greatly that of 1905. The operators in Illinois and Kentucky are seriously hampered in working their mines by the difficulty of getting reliable and competent workmen.

The Illinois production amounted to 33,275 short tons, valued at \$220,206, an increase of 16,070 short tons in quantity and of \$98,034 in value over the reported production of 17,205 short tons, valued at \$122,172, in 1904. Kentucky has fallen to second place, the output in 1905 being 22,694 short tons, valued at \$132,362. This, however, is an increase of 3598 short tons in quantity and of \$20,863 in value as compared with 19,096 short tons, valued at \$111,499, in 1904. In Tennessee, 25 tons of fluorspar were mined, but not sold.

THE PRODUCTION OF PRECIOUS STONES IN 1905.

While the United States may never lead the world in the production of gems, the value of its output of precious stones in 1905 reached the very respectable figure of \$326,350.

The largest output is from the sapphire mines, the yield of which amounted to \$125,000. Next in value are the turquoise, quoted at \$65,000. Then come the tourmalines worth \$50,000. Peridotes, crystal quartzes, and miscellaneous stones are accredited with a value of \$10,000 each. The production of aquamarines is valued at \$6,000, of kunzite, gold quartz, chrysoprase, silicified wood, and garnet at \$5,000 each, of smoky quartz and chlorastrolite at \$3,000 each, of amethyst, agate, pyrite, malachite, anthracite, and catlinite at \$2,000 each, of moss agate at \$1,500, of beryl, rose quartz, amazon-stone, and arrow points at \$1,000 each, of topaz, utah-lite, and mesolite at \$500 each, of fossil coral at \$250, and of dumortierite in quartz at \$100.

Mr. George F. Kunz, who has prepared a report entitled, "The Production of Precious Stones in 1905," which will soon be published by the United States Geological Survey, is authority for these figures.

AMERICAN AMETHYSTS.

From time to time amethysts are discovered in North Carolina, says Mr. George F. Kunz, of the United States Geological Survey, in a forthcoming report on precious stones. They are found especially in the region of Rabun Gap, Georgia, on the North Carolina border. No quantity sufficient to warrant mining seems to exist. Yet many of the stones are incomparably beautiful, second indeed to none found in foreign localities.

THE GREATEST GEM MINE IN THE WORLD.

The sapphire workings at Yogo Gulch, Montana, are being gradually developed into a great and permanent mining industry, says Mr. George F. Kunz in a forthcoming report on precious stones, published by the United States Geological Survey. Taken as a whole, the Yogo dike is perhaps the greatest gem mine in the world. It is about 4 miles long on the surface, and being a true igneous dike, descends to an indefinite depth. It is estimated that the entire content of workable sapphire-bearing rock would approximate 10,000,000 cubic yards. A mining plant is now being erected here which will quadruple the previous output and make Montana sapphire mining a very important factor in American gem production.

The stones obtained are not of large size. They range from "culls," used for watch jewels and other mechanical purposes, to gems averaging, when cut, from half a carat to 2 or 3 carats and rarely up to 5 or 6. As gems they are brilliant, free from flaws and of good color, ranging from light shades to the rich, deep blue of oriental sapphires. The Yogo crystals have an advantage for mechanical uses over East Indian stones in their form, which is largely short prismatic or rhombohedral with flat basal terminations, and hence they need much less cutting for such purposes as watch jewels. The gems are sent to Amsterdam for cutting, and yield from two-fifths to one-half that weight of finished stones.

ABRASIVE MATERIALS.

The United States Geological Survey is about to publish its annual report on the production of abrasive materials during 1905. The report takes note only of that small part of the production of these materials which is actually used for abrasive purposes.

The aggregate value of the production of the natural abrasive materials during 1905 was \$1,427,780, which is an increase of \$20,679, as compared with \$1,407,101, the value of the 1904 production. This includes oilstones and scythestones at \$244,346, grindstones and pulpstones at \$777,606, buhrstones and millstones at \$37,974, pumice at \$5,540, infusorial earth and tripoli at \$64,637, crystalline quartz, including feldspar, at \$88,118, garnet at \$148,095, and corundum and emery at \$61,464.

There is considerable variation from year to year in the value of the different abrasive materials, and this represents in nearly all cases a corresponding variation in the quantity produced. As a rule, however, the actual quantity of abrasive materials produced and put on the market in one year is increasing.

The value of the artificial abrasive materials—such as carborundum, crushed steel, and alundum—manufactured during 1905 is estimated at \$701,400, as compared with the estimated value of \$830,926 of the 1904 production, a decrease of \$129,526. This, however, is a large increase as compared with \$493,815 in 1903, and with \$390,245 in 1902.

The report was prepared by Mr. Joseph Hyde Pratt.

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ELECTRICAL SECTION.

(*Stated Meeting, held Thursday, March 22d, 1906.*)

The Mercury Arc: It's Properties and Technical Applications.

BY E. WEINTRAUB, PH.D.

General Electric Co., Schenectady, N. Y.

SECTION I.—*Structure of the Mercury Arc.*

We understand in what follows by "Mercury Arc" an arc through mercury vapors in a perfectly exhausted space.*

The *structure* of this arc varies with the conditions, such as temperature, pressure of the mercury vapor, etc. In general, we can distinguish (1) a *homogeneous* part, beginning at the

*The arc discharge through mercury vapor in an atmosphere of foreign gas is accordingly excluded from our consideration.

anode and ending at a certain distance from the cathode. This part is similar to the positive column of the ordinary Geissler discharge. We will designate it, therefore, by the name Positive Column of the Mercury Arc. (2) In the neighborhood of the cathode and following the positive column a *relatively dark space*, similar to the cathode dark space of the Geissler discharge. (3) Finally, at the cathode itself a bright patch which we will call the *cathode spot*. This spot is usually in irregular motion on the surface of the cathode.

The most important deviations from this normal structure can be summarized as follows:

- (a) The cathode dark space is the more developed the larger the diameter of the tube at a given current, or, in other words, the smaller the current density. In narrow tubes at high current densities the cathode dark space disappears completely.
- (b) If the mercury vapor pressure in the arc space gets above a certain value the positive column no more fills the entire section of the tube, but rather concentrates itself in the middle of the tube, being surrounded on all sides by a space of relatively weak luminosity and very small conductivity.

If the mercury arc is to present its normal appearance, such as described at the beginning, the mercury vapor pressure must be kept below a certain maximum value. This can be achieved either by regulating the dissipation of heat from the surface of the arc itself, or else by providing a chamber lying outside of the path of the arc, in which the mercury vapor can condense. This part of the tube will be designated by the name "condensing chamber."

In the description of the different parts of the arc that follows, we will assume that we have to deal with an arc of normal structure.

I. *Anode.*

The anode of the mercury arc can consist of any conducting material of sufficiently high melting point which does not combine with mercury. In practice, only three materials are in use, mercury itself, graphite and iron (or nickel).

When mercury is used the distribution of current at the surface is, under normal conditions, uniform all over. Only when the mercury vapor pressure goes up above the permissible limit

does the distribution become more or less localized, the arc leaving the surface mostly at the side nearest to the cathode. The heat evolved at the anode is used up in volatilizing the mercury. This increases the pressure of mercury vapor in the tube and larger condensing chambers are necessary to keep the pressure down to its normal value.

If graphite or iron are used as anodes, the arc usually leaves the anodes at those parts which are nearest to the cathode. The heat evolved at the anode serves to increase its temperature and the resulting temperature is the result of an equilibrium between two factors, the production of heat at the anode and the conduction of heat by the mercury vapor surrounding the anodes. It increases with the current and its upper limit is only determined by the melting point or boiling point of the material. The heat evolved at the anode is due to the existence of a certain potential drop at the surface of contact between the anode and the arc. The magnitude of this "anode polarization" depends on the material used, its temperature, and is therefore not a characteristic quantity.

2. *Positive Column of the Arc.*

The positive column presents in the normal arc a uniform appearance, with no striations whatever. Only in the case of very small current and seemingly *only in the presence of foreign gases* do striations appear. This case is interesting, as in contradistinction to the Geissler discharge, the striations appear here at low voltage. The potential drop in the positive column has a certain value per unit length and is the smaller the larger the diameter of the tube. A *simple* relation between the diameter and the drop does not exist. In a tube of 1.8 cm. diameter the potential drop per cm. is equal to about 0.72 volt. The potential drop depends, of course, on the pressure of the mercury vapor in the tube. The above given value refers to a good vacuum and to the case when the pressure of mercury vapor is kept low by a condensing chamber, but no exterior cooling means are used. The drop per unit length in the positive column, being thus variable, is not a characteristic quantity of the arc.

SECTION II.—*Properties of the Cathode.*

The properties of the cathode are of such importance that a special chapter must be devoted to them. The processes going

on at the surface and in the neighborhood of the cathode are essential both for the maintenance and for the initial starting of the arc.

(a) The following experiments will show the role of the cathode in the *starting* of the arc:

The tube ABC (Fig. 1) has two cups, B and C , filled with mercury, and a graphite electrode A . B and C are connected to one source of direct current, B and A to another; let us imagine that the connections are made at first in such a way that B is the common *negative* pole of the two sources. If the electrodes B and C are brought into contact and separated the arc BC starts, B being its cathode. We find then that on closing the switch of the circuit of the other generator, G_1 , the arc AB starts instantaneously.

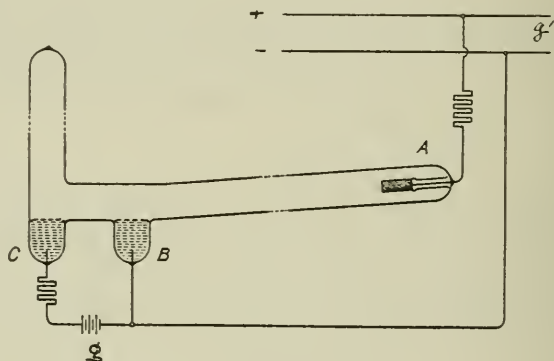


Fig. 1.

If the connections are changed in such a way that B is the common *positive* pole of the two sources and the arc BC started as before, the arc AB does not start on closing the switch. This *dissymmetrical* behavior shows how entirely different the electrode B behaves when it is cathode and when it is anode of an arc.

The experiment succeeds also when the graphite anode A is replaced by a mercury electrode. In this case, however, the arc AB may sometimes start up, even when B is anode, for the reason that the mercury cathode A can be rendered active by other causes than by an already existing arc.

Since ordinary mercury vapor is a non-conductor and since the experiment described shows that the excitation of the ca-

thode by means of the auxiliary arc BC is necessary for the starting of the arc AB , we are forced to the conclusion that *the production of the conducting vapor takes place, at least in the very first stages of the development of the arc, at the surface of the negative electrode.*

In the ordinary process of starting an arc by contact it is impossible to separate the function of the cathode from that of the anode. The experiment described above represents for an arc in vacuum such a separation and shows the complete difference between the behavior of the cathode and that of the anode, a difference which is of fundamental importance for any theory of the arc discharge.

The experiment succeeds well only when the vacuum is very good, *i. e.*, in absence of foreign gases, and also in absence of too large an excess of ordinary mercury vapor. In other words, the experiment succeeds well at ordinary temperature in a perfectly exhausted tube, the anode and the walls of the tube having been previously freed from all gases absorbed on their surface. If the vacuum is not perfect or if the tube is hot, so that too much mercury vapor is present, the starting of the arc AB is not instantaneous and one can see the conducting ("ionized") vapor spreading slowly from the cathode B . When this ionized vapor reaches the anode A the arc AB usually starts, although if the vacuum is too poor the starting may not take place.

(b) *Role of the Cathode in the Maintenance of the Arc.*

In the chapter on the stability of the mercury arc we will see that under given conditions there exists a minimum value of current at which the arc is stable and below which it goes out. Under ordinary conditions this minimum value lies at about three amperes. Experiments have shown that the instability of the arc below the minimum value is due, to a large extent, to the *wandering* of the cathode spot on the surface of the mercury cathode.

The fact that there exists a bright patch on the cathode and that this patch constantly and irregularly wanders about on the surface of the mercury has already been mentioned above. The cause of the wandering has not yet been ascertained.

This wandering can be avoided in two different ways. The first way consists in the use of a platinum or iron wire protruding above the surface of the mercury. If the current is not

large, say not above five amperes, the cathode spot fixes itself around the wire at the point where the wire crosses the mercury surface. The second way consists in the use of a narrow tube of refractory material, such as silica or porcelain, the cathode spot being produced by means to be described later (Section 3) on the mercury surface inside this narrow tube. In this case the spot remains always inside of that tube.

Now, if the cathode spot is fixed by either of these two methods, the value of the *minimum current is considerably lowered*. In the case of a narrow silica tube surrounding the cathode spot, the value of the lower limit is about $1\frac{1}{2}$ amperes; in the case of the platinum wire about .9 ampere. This result, viz., that the wandering of the cathode spot on the mercury surface causes the arc to go out, is again a strong argument in favor of the theory that the production of the current carrying material takes place in the cathode spot, every disturbance of that process, such as is caused by the wandering of the cathode spot, being able to stop that process altogether.

(c) *Polarization of the Cathode.*

At the surface of the cathode there is a potential drop equal to about five volts. This quantity is independent of the current, mercury vapor pressure, etc. The polarization voltage at the anode, as well as the drop in the arc itself, were shown to be variable quantities.

The cathode spot is the larger the larger the current. It is quite possible that when the current is such that the cathode spot covers the whole surface of the cathode, further increase of the current would change the value of the cathode potential drop.

(d) *Disintegration of the Cathode.*

It is possible to realize mercury arcs, that is, arcs through mercury vapors in an exhausted space, with a cathode consisting of any conducting material. If in the tube *AB* (Fig. 2) the graphite electrode *A* is connected to the negative pole of a direct current circuit and *B* to the positive pole, and the electrodes brought into contact by shaking, an arc starts with the graphite as cathode. These solid cathodes, as I will call them, for the sake of brevity, show the same behavior with respect to the starting of the arc as an ordinary mercury cathode. Thus the fundamental experiment described in the beginning of this Sec-

tion can be repeated with a solid cathode. [*B* (Fig. 1) is made of graphite, iron or any other conducting material.] Care, of course, must be taken to free that electrode from absorbed gases before trying the experiment. With these solid cathodes another phenomenon, however, is observed, viz., the *mechanical disintegration of the material of the cathode*. The cathode spot exists also on the solid cathodes. A well defined and sharply outlined red hot spot wanders irregularly on that surface and at the same time small particles of the material are being incessantly projected from that spot, collecting on the walls of the tube. *This disintegration of the cathode represents another essential difference between*

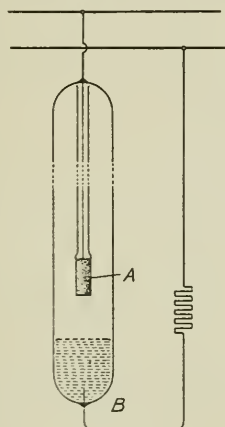


Fig. 2.

the anode and the cathode of the arc in metallic vapors in an exhausted space. In the case of one material, viz., of charcoal, one succeeds in obtaining on the surface of the electrode *sharply outlined, fine grooves which show the path followed by the cathode spot*. Measurements of the dimensions of these grooves, their width and depth at different currents under different conditions, might lead to interesting conclusions. In the case of all other materials every particle disintegrated electrically causes, by loosening the structure, other particles to separate mechanically in such a way that no trace of the cathode spot is left on the surface. The material produced by the disintegration of the cathode differs usually in its physical properties from the original material of the cathode. If graphite, for instance, is used, the

disintegrated material has no cohesive properties, is a very poor conductor and leaves no trace on paper. The chemical properties, however, remain the same.

SECTION III.—*Starting of the Mercury Arc.*

The methods usually used to start an arc can be described as the "*contact*" method and the "high potential" method.

In the first method, which is used in the carbon arc, in flame arcs, etc., the arc is started by bringing the two electrodes into contact and separating them.

The second method consists in sending for a short time a discharge from a high potential source through the space between the two electrodes and then making the low voltage source follow the path of the discharge of the high potential. (This method was, I believe, first used by Herschel.) Both methods have been used in the case of the mercury arc by Arons, Cooper Hewitt, myself and others.

In the case of the mercury arc the contact method has taken different forms. Arons used a  shaped tube, the tube being partially filled with mercury and the two mercury surfaces brought in contact by shaking. In another arrangement one of the legs of the tube is long and connected at its lower end by means of a rubber tube to a vessel filled with mercury. By lowering or raising this vessel the two mercury surfaces can be brought into contact and subsequently separated.

One form I gave to this method is that of a straight horizontal tube, with two cups filled with mercury. By inclining the tube a stream of mercury is caused to flow from one electrode to the other and this establishes contact for a short interval of time. This movement of the tube can be produced automatically by a current flowing through magnets in shunt with the tube.

A similar arrangement has also been used by Cooper Hewitt, the shaking of the tube being done by hand. It is obvious that a number of other ways can be found, such as heating the mercury and causing it to expand, etc., all for the purpose of bringing the two mercury surfaces in contact.

The high potential method has been used by Arons and then afterwards by Peter Cooper Hewitt.

A "kicking" coil and a quick break switch are placed in shunt

to the mercury tube. On opening the quick break switch the high potential created at the end of the reactance discharges through the space between the electrodes in the mercury tube, whereupon the low voltage follows in the path of the discharge and establishes an arc.

The Sidebranch Method—Excitation of the Cathode.

The new method for starting the mercury arc that I proposed is founded on the cathode properties which have been described in the previous chapter. We have seen that if the negative pole

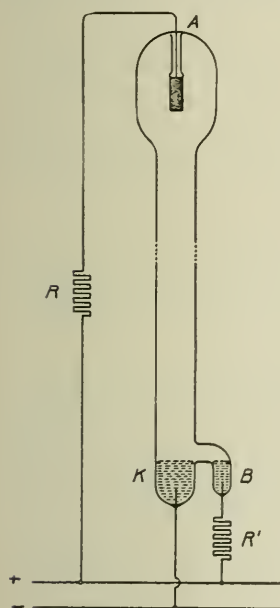


Fig. 3.

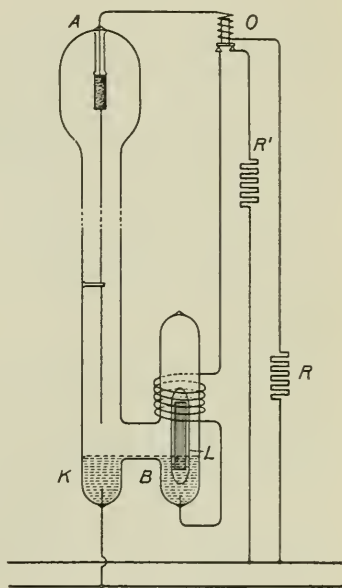


Fig. 4.

which is to be the cathode of the arc is excited by an auxiliary arc and the vacuum in the tube is good, an arc will instantly establish itself between this cathode and any anode.

The tube represented in Fig. 3 shows one of the ways in which this property can be used for the purpose of starting an arc. *K* represents a mercury surface connected to the negative pole of the source of direct current. *A* represents the electrode which is to be the anode of the arc. *B* is also connected to the positive pole of the source of direct current. *R* and *R*₁ are two resist-

ances. If by slight shaking of the tube the electrodes K and B are brought into contact and separated, a short arc is formed which excites the cathode K and causes the starting of the main arc, AK . The auxiliary arc, KB , can then be extinguished by opening a switch in the line of the auxiliary anode B . The side tube KB is called "the sidebranch," B the auxiliary or "starting" anode, and the method of starting is called the "*sidebranch method*." The auxiliary arc, KB , instead of being started by shaking, can, of course, be started automatically in many different ways; one of the first used is shown in Fig. 4. The mercury surfaces of the cathode K and the auxiliary anode B are normally in contact. S is a solenoid, L a bundle of iron wire. The current, on closing the switch in the line, goes through the solenoid and the mercury in B and K . The iron core L being lifted, the contact between KB and K is broken, whereupon the little arc BK starts the main arc KA . O is a magnetic cut-out which opens the circuit of the sidebranch when the current in the main arc reaches a given value.

Beside this arrangement, a number of others for the purpose of automatic starting of the sidebranch were used; they are, however, not as simple as the electro magnetic one just described.

The starting of the arc by means of the sidebranch method is instantaneous only when the vacuum of the tube is exceedingly good and the pressure of the mercury vapor is not too high. The starting of the main arc is accordingly instantaneous when the tube is perfectly cold or immediately after the arc is put out.* If the vacuum is not perfect or the tube hot, the starting of the main arc takes some time. This is the same phenomenon as that which we described in the paragraph on the properties of the cathode and would suffice to make the practical value of the sidebranch method of starting rather small. The difficulty has, however, been overcome by suspending from the anode a carbon filament of high resistance and of such a length that its lower end is but a few inches away from the mercury cathode. For the starting of the arc this means a shortening of the distance between the anode and the cathode. After the arc is started a very small current only flows through the carbon filament, the

*The ionation in the path of the arc persisting for a short while.

arc having a much lower resistance. The filament is seen in Fig. 4.

Out of the use of this carbon filament as a device for the facilitating of the starting of the mercury arc, another method of starting developed. The carbon filament, instead of reaching within a certain distance from the cathode, actually touches the latter, so that, on closing the switch, the current finds a way from the anode to the cathode, through the carbon filament.

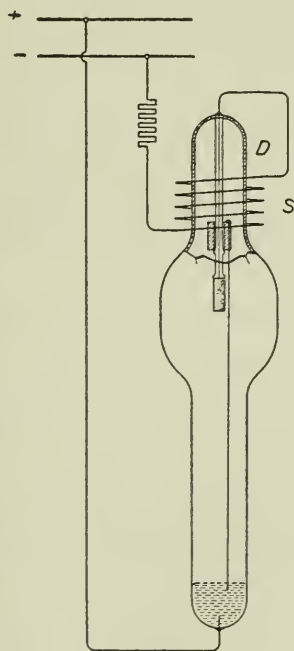


Fig. 5.

This current is caused by energizing a solenoid, to separate the filament from the mercury cathode, either by lifting the filament or by lowering the level of the mercury. The little arc thus formed between the end of the filament and the mercury cathode instantaneously develops into the main arc between the mercury cathode and the anode. An arrangement in which the carbon filament is lifted is shown in the next sketch (Fig. 5.)

The carbon filament is attached to an iron cylinder which forms a sliding contact with the rod *D*, which rod is directly connected to the leading-in platinum wire. The current at first

flows through the solenoid S , the leading-in platinum wire, carbon filament, mercury cathode, back to the source. The energized solenoid in pulling up the iron cylinder to which the carbon filament is attached starts the arc. In some of the arrangements the upper part of the rod D is coated with an insulating layer of glass, so that when the sliding cylinder is pulled up, the current flow through the carbon filament completely ceases and the carbon filament is cut out of circuit. This lamp is given the name of the "Lift-Up Filament Lamp."

An arrangement in which the mercury level is lowered was designed by C. P. Steinmetz. An iron plunger, the upper part of which is drilled out and carries mercury in the hole, floats in the mercury cathode so that in the normal condition the filament is in contact with the mercury in the plunger. A solenoid, when energized by the current, pulls the plunger under the surface of the mercury and by breaking contact, starts the arc. This type of lamp is called the Plunger Lamp.

SECTION IV.—*The Stability of the Mercury Arc.*

The conditions of stability of the mercury arc are of a rather complicated nature and depend on a number of factors. We shall limit ourselves to the consideration of the two most important cases.

1st. *Mercury Arc with a Condensing Chamber.*—We shall first consider the arc placed in a space of ordinary temperature and *provided with a condensing space, certain parts of which remain at a temperature not much above the surrounding temperature.* The mercury arc such as is used for purposes of illumination, belongs, with a few exceptions, to this type.

In this case the potential across the arc at first diminishes as the current increases, until a certain point is reached above which the variations of potential and the current have the same sign. The potential drop across the lamp meant is not the one which is established immediately after the current is changed, but rather the one which corresponds to the equilibrium, the equilibrium being reached only after a certain time. Let A be the value of current which corresponds to the minimum value of the potential drop across the arc. Then it is obvious that for currents below the one corresponding to A the arc is in an unstable condition, since to

a slight diminution of current there corresponds an increase of voltage across the tube, which causes in its turn a diminution of current, the process going on until the voltage drop comes near to the impressed voltage and the arc goes out.

For currents above the value A the arc is in a stable condition (the current being, however, not too high, since then the condensing chamber is no more at a sufficiently low temperature.) These considerations show that there exists for a normal arc a minimum current below which the arc is unstable and goes out. The experiment confirms this result. That minimum value is usually in the neighborhood of three amperes. This explanation of the existence of a minimum current, although in all probability correct from a formal point of view, does not give us any insight into the physical cause of the phenomenon. This cause was partly pointed out in Section 2.

In all the considerations given above it was assumed that a certain regulating resistance is in series with the arc, but no reactance. If a large reactance is placed in series with the mercury arc it changes the conditions of stability altogether. This is similar to what was known in the case of the ordinary carbon arc. With a large reactance in series the minimum current at which a normal arc can run is much lower than without reactance and is the lower the larger the reactance. With a sufficiently large reactance it is easily possible to have an arc with a current of only a few tenths of an ampere. The action of the reactance, which consists in introducing an e. m. f. every time the current tries to diminish, is too obvious to require any discussion.

2d. *The Arc Without a Condensing Chamber.*—If the arc is not provided with a condensing chamber its stability depends a good deal on the conditions of radiation and heat conduction on the surface of the tube itself, the temperature rising until thermal equilibrium is reached between the energy input and the heat radiated from the surface of the tube. The temperature corresponding to this equilibrium and accordingly the pressure of mercury vapor in the tube being much higher than in the case of the arc with condensing chamber, the potential drop across the arc is considerably higher, and the curve connecting this potential drop with the current is also different. It is, however, possible to have an arc run stable under these conditions

by a proper choice of the impressed e. m. f., the resistance in series with the arc and the external temperature.

SECTION V.—*Arcs in Metallic Vapors Other than Mercury.*

The arc in the vapors of other metals which are sufficiently volatile, has in general the same properties as the arc in mercury vapors. The investigation included the following metals: Potassium, sodium, alloys of the two as well as with lithium, bismuth, lead, tin, zinc, cadmium and alloys of those metals which have a low melting point, such as Wood's metal, finally amalgams of all the above-named metals, etc. In most cases the arc was produced inside of a glass vessel, although in the case of the less volatile metals a silica vessel was often used, the silica vessel containing the metal and being suspended inside of a glass tube or bulb. In the case of the alkali metals and of the easily fusible alloys of the other metals, such as Wood's Alloy, etc., it is easily possible to produce in a well exhausted tube arcs of practically any desired length. Those arcs have essentially the same properties as the ordinary mercury arc. A cathode spot exists on the surface of the metal, whether this metal be liquid or solid. This cathode spot is wandering about the surface and all the experiments that have been described in the case of the mercury arc can be repeated here. The anode can be made of any material and consisted in the experiments mostly of a piece of graphite.

The spectrum emitted changes of course with the nature of the metal. The amount of light is usually small and the efficiency small. This is due to the small amount of material in the space, in consequence of the low vapor tension of these metals. If the exhaustion is made by means of a mercury pump the small amount of mercury vapor present in the space is sufficient to give to the arc immediately after starting the character of a mercury arc. As the material of the cathode volatilizes the mercury vapor spectrum is being replaced by the spectrum of the corresponding metal.

If amalgams are used the spectrum of the arc shows lines due to the mercury as well as to the metal dissolved in it. The proportions in which the radiations of the two metals are represented in the spectrum depends, of course, on the percentage of the metal dissolved in the mercury. It also depends on the

current. When dilute amalgams of alkali metals are used the lines due to sodium or potassium begin to appear only when the current reaches a certain value. The addition of the alkali metals or of the metals like calcium, strontium, link, etc., could be used for the purpose of improving the color of the light emitted by the mercury arc. (See Section Technical Applications.)

The drop of potential across the arc, as well as the single drops at the electrodes, are of the same order of magnitude whatever the metal used.

SECTION VI.—*Alternating Current Phenomena in the Mercury Arc.*

Alternating voltages of moderate value are incapable of maintaining an arc in mercury vapors in an exhausted space. The spark formed on separating the two electrodes dies out, no matter how large the current it carries.

This phenomenon is easily accounted for on the basis of the principles laid down in the Section on the cathode properties. An arc cannot exist without a constant source of conducting material at the negative electrode. If the production of conducting material ceases at the cathode, the arc is bound to go out, unless by some means the cathode surface is rendered active anew. In the case of an alternating voltage, however, the negative pole changes from one mercury surface to another. The emission of negative ions which is started by the initial separation of the electrodes dies out and with it the arc. The conditions change when the alternating voltage is high enough to render the cathode active at each alternation. This we will discuss later; we limit ourselves here to the case of an alternating voltage of moderate value.

In this case, one way of making a *current derived from an alternating source pass through mercury vapors* is to keep one of the electrodes active by making it the cathode of an auxiliary direct current arc. The arrangement is the same as on Fig. 1, with the difference that g^1 is an alternator.

CB is a direct current arc with B as cathode. B and A are connected to the terminals of a source of alternating voltage. The electrode B being constantly kept active by the direct current, the half wave of the alternating voltage, for which B

is the negative pole, can send a current through the space between B and A . The half wave of opposite sign cannot pass. Accordingly, we get in the circuit of BA a pulsating unidirectional current. The interest of this arrangement is obvious, as it gives us a way of deriving unidirectional, although pulsating current from an alternating source.

By providing two auxiliary direct current sources and connecting the alternating current source to the two cathodes of the direct current arcs, an *alternating* current can be made to pass between those two cathodes. The discussion of this case,

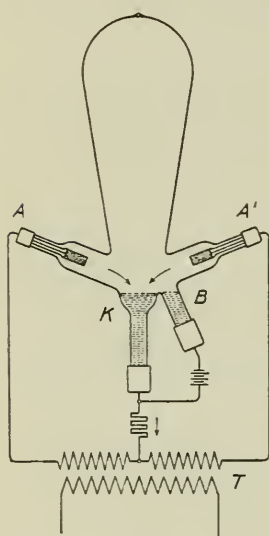


Fig. 6.

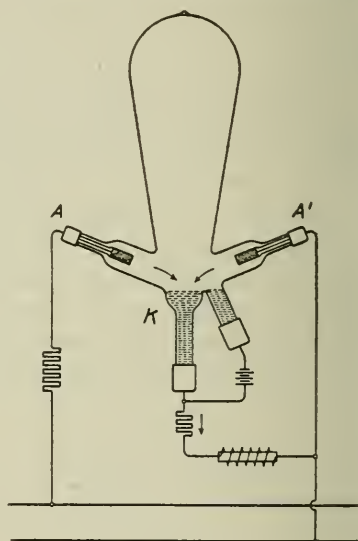


Fig. 7.

in spite of its interest, I must omit, in order not to make this article too voluminous.

Returning to the first arrangement, in which only one direct current source is used, we see that a pulsating current is derived, only one half wave being utilized. To utilize both half waves and superimpose them in the same direction in the same circuit, an arrangement can be used which is represented in Fig. 6. There are two anodes in the tube to which two terminals of the secondary of a transformer are connected. The middle point of the secondary is connected to the cathode. An auxiliary direct current source, BK , serves to excite the

cathode. As is easily seen, for each direction of the alternating voltage one half of the secondary sends a current through the tube in the right direction—that is, in such a direction that K is cathode. The current derived in the wire connecting the cathode to the neutral point of the transformer consists now of an uninterrupted series of pulsations. It passes through zero every half period and the auxiliary direct current source has only the function of keeping the cathode active during those intervals of time when the alternating current is zero or in the neighborhood of it.*

The use of a direct current for the excitation of the cathode can be dispensed with *if the property of reactances* of accumulating energy when the current flowing in them increases and discharging that energy when the current begins to diminish, is made use of. A rectifier constructed on this principle and in which only one half wave is rectified, is shown in the next sketch (Fig. 7.)

The electrodes A and A^1 are connected to the two poles of the alternating current source. Between A^1 and the middle electrode K , a reactance coil is placed. If by any means K is made for an instant cathode, either by an auxiliary direct current or by preliminary contact of K with A , the following processes go on: The half wave for which A is anode passes in the direction from A to K , then through the reactance and when this current begins to diminish, the reactance discharges mostly through the space A^1K in the direction shown by the arrow. If this discharge takes a sufficiently long time, the cathode is kept going during that half period, when otherwise there would be no current.

To get both half waves rectified by the use of reactances, the arrangement shown above must simply be made symmetrical by the use of two reactance coils, in the way shown in the next sketch (Fig. 8.) It will be seen that both half waves, as well as the discharges of the reactance coils, have the same surface, K , for cathode, and that in the wire connecting the cathode to the point between the two reactance coils a continuous direct current is flowing. The load, which can con-

*Of course the Graetz connection could be used; it is, however, less advantageous than those described.

sist of a resistance or storage battery, etc., has therefore to be placed in this line.

It will readily be seen that the result achieved in the last arrangement by the use of two reactance coils can also be achieved in the arrangement described above (Fig. 6), where the neutral wire of a transformer is used by simply introducing a sufficiently large auxiliary reactance into the neutral wire between the middle point of the transformer and the cathode.

SECTION VII.—Arcing.

The two electrodes, A and A' , in the rectifier described last, the anodes of the rectified currents, are, when the arcs run,

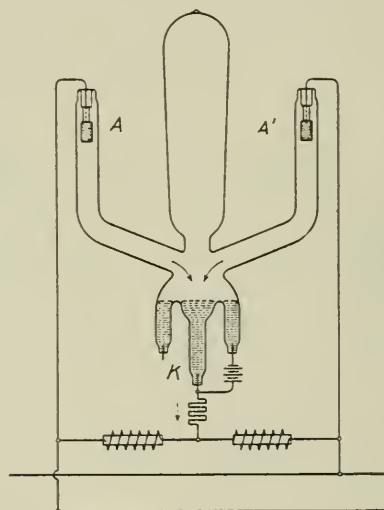


Fig. 8.

surrounded by highly conducting vapor and it is at first glance surprising to find that no arc develops between them. The absence of an arc discharge directly between the two anodes is easily accounted for on the principles expounded above by the absence of a cathodic center on either one of the two anodes. If such a cathodic center is for one reason or another formed on one of the two anodes, an arc discharge between the two anodes takes place, and this phenomenon was termed "arcing of the rectifier." In absence of such a cathodic center a very small "leakage current" probably exists between the two elec-

trodes (since one always finds currents of the order of magnitude of 1 milliamperes between two exploring electrodes placed in the mercury arc and to which an e. m. f. of moderate value is applied.)

The conditions under which this leakage current develops into an arc discharge—in other words, the conditions under which in presence of conducting vapor, a cathodic center is produced on a negatively charged surface, are of considerable theoretical interest. The following experiments are of interest in this connection:

Let us return to the experiment by means of which we illustrated the importance of the cathode in the starting of the mercury arc. The tube is the same as that represented on Fig. 1 and the connections are also the same as there. The only difference is that the anode *A* is made of *mercury* instead of graphite. The phenomena described in the corresponding paragraph remain the same, whatever the material of the anode. If *B* is made cathode by starting the arc *BC*, the arc *AB* starts up instantaneously (provided there is a good vacuum in the tube.) If the electrode *B* is the common anode the arc *AB* does not usually start. However, when the ionized vapor which diffuses from the arc *CB* fills the space between the electrodes *B* and *A*, a small leakage current between *A* and *B* takes place. If *A* is graphite or iron this state continues indefinitely. If *A* is mercury the arc may eventually start between *B* and *A*, *A* becoming the cathode of the new arc. The experiment can be given even a more effective form by placing the cup *A* between the electrodes *B* and *C*. In that case, in spite of the presence of the highly conducting vapor of the arc *C*, a small leakage current only exists between *A* and *B*. It is, however, more difficult to maintain this condition and the arc starts rather readily.

In these two experiments with direct current arcs we are therefore confronted with the same problem of the formation of a cathodic center on the surface of a negatively charged body. The experimental results obtained in the study of this question, the practical importance of which is obvious from the connection with the arcing of the rectifier, can be summarized as follows:

(a) The ease with which a cathodic ionization center forms

on the surface of a negatively charged electrode varies with the material of which that electrode is made.

The ease of formation seems to be connected with the boiling point of the material, and is, therefore, unless certain necessary precautions are taken, greater in case of mercury than in the case of solid electrodes.

In the rectification of very high potentials, such as given by an ordinary induction coil or high potential transformer (say 30,000 to 40,000 volts) and very often also in the rectification of voltages somewhat below (around 10,000) the influence of the material on the ease of the formation of a cathodic center is shown in a very striking way. The graphite anodes are usually fastened by means of leading-in platinum wires, which are insulated either by a coat of glass or by glass tubes surrounding them. Experiments show that at the high voltages mentioned above a cathodic center is more *liable to form on the glass which surrounds the platinum wire than on the graphite*. A bright cathode spot appears on the glass, causing it to melt and volatilize. The gases evolved spoil the vacuum, and the cracking of the seal often destroys the tube. The fact that on glass and similar materials the cathode spot forms more readily than on graphite or iron is again probably connected with the fact that glass can give off vapors of sodium and similar metals.

(b) *The Influence of the Potential*.—It is natural that the formation of the cathode center takes place the more readily the higher the potential applied. In fact, one of the older methods of starting a mercury arc by the "kick" of a large inductance is based on the formation of a cathode center under the influence of high potential.

In the case of the mercury arc rectifier the danger of arcing between the two anodes increases as the voltage applied to the anodes increases. With graphite anodes, if necessary precautions are taken, the upper limit of potential at which arcing takes place has not yet been determined.

The formation of a cathodic center on a negatively charged mercury surface under the influence of high potential can be shown by the following experiments:

(1) Let *AB* (Fig. 2 only with reversed connections) represent a tube in which *B* is a mercury surface connected to a

negative pole of a source of unidirectional low voltage and *A* is a graphite anode connected to the positive pole of the same source. If the distance between *A* and *B* is not too large (in some of the experiments it was, however, as large as 8 to 10 inches) mere shaking of the tube is apt to start the arc between *A* and *B*. It is obvious that the mechanical shaking can act only by producing a static charge of high potential on the surface of the mercury.

The next experiment seems to show that a considerable factor is the electric field intensity near the cathode.

(2) A tube *AB* has two mercury electrodes. One is of a very small surface, the other of a very large. On connecting these two electrodes to the secondary of a high potential transformer, cathode spots appear in the form of sharp, brilliant points only on the small surface, provided the current in the tube is kept low. This is explained by taking into account the different shape of the mercury surfaces constituting the two electrodes. The radius of curvature being much smaller in the case of the small electrode and accordingly the field intensity higher, the negative particles are propelled with greater force into the space and a cathode center forms more readily. If a direct current ammeter is placed in the circuit of the tube its deflection shows that rectification takes place. The direction in which the current predominates is, however, not necessarily the one for which the small electrode is cathode: At very small currents the current of opposite direction usually predominates, showing that the negative current, which leaves the large surface *B* in form of a *homogeneous* discharge, equally distributed over the whole surface, is larger than the negative current, which leaves the small surface in localized cathode points. As the current is increased the two opposite currents become equal, and when the cathode points on the small electrode grow sufficiently large, the negative current starting from them begins to predominate. If cathode spots form, as they often do, on the large surface *B*, they usually form in the neighborhood of the glass, at the place where the curvature of the mercury surface is smallest and the electric force perpendicularly to the surface accordingly the highest.

(c) *The Influence of the Position of the Anodes with Respect to the Cathode.*

We come here to a phenomenon which is surprising and the cause of which is not yet certain. The ease with which the cathodic center forms on one of the anodes of a high voltage rectifier depends on the relative position of those anodes with respect to the cathode. If the anodes are placed directly above the cathode arcing takes place more readily than if the anodes are placed at a certain angle to the perpendicular erected on the mercury surface and the danger of arcing is the smaller the larger that angle. If of the two anodes one is placed perpendicularly above the mercury cathode and the other either at a certain angle or even below the mercury level, the arcing, if it does take place, invariably has its cathodic point on the anode which is directly above the cathode. It seems as though the ionized vapor that usually shoots out from the surface of the cathode in a perpendicular direction (and is probably of an origin similar to the cathode rays) has some peculiar effect on the surface of the anode which facilitates the production of a cathodic center of ionization.

SECTION VIII.—TECHNICAL APPLICATIONS.

I. *The Arc as a Source of Light.*

The luminous efficiency of the mercury arc in any of the forms described in Section III is quite high. Measured with a flicker photometer, which is the only one allowing comparison of lights of different color, this efficiency varies under different conditions between say .25 to 1 watt per candle, the watts meaning the consumption of energy in the arc itself. Under ordinary circumstances about 20% of the watt consumption in the arc is wasted in the ballast resistance (except in series lighting where no resistance is necessary) and some part of the light is also absorbed in the globe by which the arc itself must usually be surrounded. The physiological effects of the light on the human eye and the distribution of light being of different nature than in most other sources of artificial light, the above given numbers are of considerably less practical value than actual experiments made for instance with the luminometer—that is, an apparatus by means of which the distinctness of objects at a certain distance from the source can be ap-

proximately determined. These experiments show also that the mercury arc is a highly efficient source of light.

The life of the mercury arc lamp in one of the shapes described in Section III is very considerable, in some cases amounting to 3000 hours and more. In the course of time the glass of the tube in which the arc is enclosed blackens somewhat (in consequence of a chemical change in the glass) and in lamps with a carbon filament usually some blackening takes place, due to a deposit of carbon on the walls. This blackening causes a diminution of efficiency in time which amounts to about 20% at the end of the life.

The lamp needs no attendance, as there are no electrodes to replace.

Other advantages of the lamp are the fact that relatively small units can be made (the units now made consuming 160 watts) and the diffused distribution of light in contradistinction to the concentrated sources of light represented by other arcs.

All these advantages would certainly cause this lamp to be an important factor if it were not for the nature of the light emitted, which is practically devoid of red rays. In spite of this, the lamp is being used and will probably be used more and more extensively for purposes where this absence of red rays and the corresponding discoloration of objects is of little importance. In street lighting, the lighting of parks and suburbs, as well as of factories, drafting rooms and similar places, the lamp seems to be very suitable. The mercury arc lamp is essentially a direct current lamp. An alternating current lamp was also constructed and used, built on the same principle as a mercury arc rectifier, the starting device being similar to that used in the case of the direct current arc. The construction and connections are, however, somewhat more complicated.

The methods attempted for improving the quality of the light were as follows:

(a) *The use of ordinary incandescent lamps in series with the mercury arc.* The General Electric Company has developed the so-called Orthochrome Mercury Arc Lamp, in which a number of incandescent lamps in multiple are placed in series with the mercury arc, the incandescent lamps burning at a normal efficiency. The whole is enclosed in a Holophane globe,

which serves the purpose of blending the two lights of different colors. This system has, of course, a lower efficiency than the mercury arc alone and also leads to somewhat larger units.

(b) *The use of amalgams of the alkali metals and of the metals of the alkali earths.*—In Section V we saw that by adding metals like potassium, sodium, lithium, calcium, etc., to the mercury, the spectrum of the arc can be changed. The practical application for the purpose of improving the color of the mercury arc meets, however, with considerable difficulties and disadvantages of which I mention the attack on the glass by the alkali metals, the lowering of the efficiency, etc.

(c) *Use of fluorescent bodies which have the property of trans-*

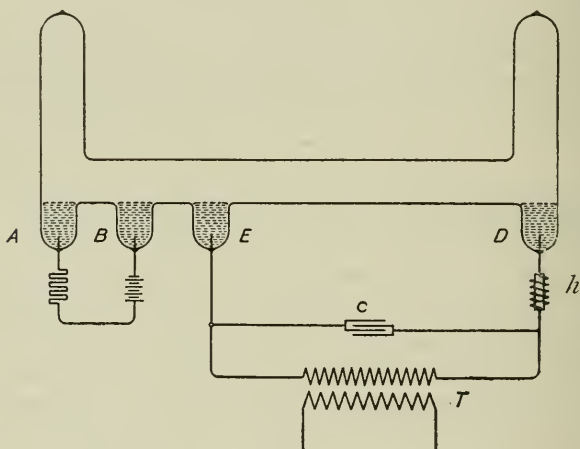


Fig. 9.

forming the violet and green rays into those nearer the red end of the spectrum.—Unfortunately none of the substances known possess this property in a degree sufficient for practical purposes; also this transformation is very wasteful.

(d) *Change of the nature of the discharge through the mercury vapors.*—The spectrum of the light emitted by the discharge through vapors or gases depends on the nature of the discharge. Work in this direction for the purpose of improving the color of the mercury arc has given promising results. One of the experiments, showing the essentials of the phenomenon, is illustrated in the sketch (Fig. 9.)

T is a transformer of not too small a capacity, *C* condensers,

h a small inductance; *AB* is a direct current arc which supplies ionized vapor, this ionized vapor filling the space between the two other electrodes, *E* and *D*. Under proper conditions the discharge of the condenser between the electrodes *E* and *D* has a spectrum rich in red rays, the arc *ED* giving a brilliant white light.

II. *Use of the Mercury Arc Rectifier.*

(a) *The constant potential rectifier.*—The mercury arc rectifier represents so far the best solution of the problem of transformation of alternating to direct current, so long as the power to be transformed is not very large. The power depending on the two factors, the voltage and the current, we will consider the two separately.

The current that can be transformed by means of the mercury arc rectifier has theoretically no limit. Practically, however, one is limited by the difficulties of introduction of large currents into an exhausted glass vessel and more yet by the difficulties in dissipating the heat disengaged in the rectifier itself. Both difficulties may be overcome by a change of the material, of which the rectifier is now being made (*viz.*, glass.)

The voltage which can be rectified by means of the mercury arc rectifier is exceedingly high. In connection with this I must refer to the section in which arcing is discussed, and from it will be seen that the voltage rectified can be the higher, the smaller the current.

The magnitude of voltage that can be rectified makes the mercury arc rectifier infinitely superior to the electrolytic rectifier.

The efficiency of the mercury arc rectifier depends on the voltage to be rectified and is the higher the higher that voltage. This is due to the fact that the voltage consumed by the rectifier itself is a constant quantity, independent of the current. In the ordinary constant potential rectifiers that loss amounts to about 17 volts. The efficiency of the mercury arc rectifier for ordinary voltages of 100 to 200 volts is therefore much higher than that of electrolytic rectifiers. The power factor can also, by a proper choice of the reactances, be made as high or higher than 90%.

The high efficiency and simplicity of the mercury arc rectifier cause its use to spread every day. It is used especially for charging storage batteries in connection with automobile and telephone work, also in a number of other cases, such as driving small direct current motors from an A. C. source, feeding induction coils in connection with an interrupter, etc.

(b) "*Constant Current*" Rectifier.

The constant current rectifier differs from the constant potential only in the fact that a constant current transformer is used instead of a constant potential transformer. The use of the constant current rectifier in connection with direct current arc lamps, especially the Magnetite Lamp, also developed in the Research Laboratory of the G. E. Co., is of growing importance. A number of installations have been made in which 25 to 75 Magnetite Lamps, each consuming 80 to 100 volts, are used as a load in the direct current side of a constant current arc rectifier, to the alternating current side of which about 15000 to 20000 volt are applied. The description of this system of lighting alone could be a subject for a separate paper, so I cannot go into detail at this place.

(c) *The High Frequency Rectifier.*

The mercury arc rectifier is capable of rectifying alternating currents of frequency as high as that given by a condenser discharge—that is, of the order of magnitude of 10^6 to 10^{10} oscillations per second. So far, no limit could be found, although it is practically impossible to prove that the rectification is complete. This property can be used in connection with wireless telegraphy, the mercury arc rectifier serving to rectify the oscillations received in the antennae, and a sensitive direct current galvanometer used in connection. The arrangement of the receiving station is represented in the sketch (Fig. 10.)

T is the transformer transforming the oscillations to higher potential and provided with a neutral wire. The connections to the rectifier are the same as those described in Section VII so that both half waves are rectified. *G* is the galvanometer. An auxiliary direct current source, consisting of a well insulated storage battery of about 20 volts, runs the sidebranch arc, so as to keep the cathode constantly active. It is probable that the arrangement is not as sensitive, as a telephonic

receiver. It has, however, the advantage that telegrams can be registered.

SLOWLY MOVING CATHODE RAYS AND UNILATERAL CONDUCTIVITY

(a) *Starting of the Arc.*—The experiments described in the paragraph on the starting of the mercury arc by means of an auxiliary arc may be explained by the assumption that rays similar to the cathode rays of a Crookes tube are emitted from the cathode and propagate through the space with a velocity which depends on the amount of foreign gases or mercury vapor present in the space. If the vacuum in the tube is very

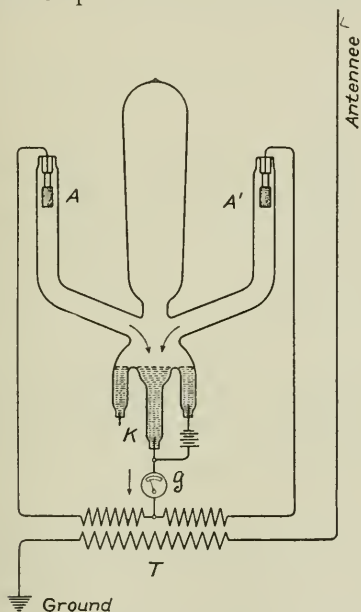


Fig. 10.

high these cathode rays move very rapidly and when they reach the anode a conducting bridge is established between the cathode and the anode. When the vacuum is poor, or when a great amount of mercury vapor is present, the speed of the cathode rays is reduced considerably, and through collision with the inert molecules and the recombination of the ions to neutral particles, a condition can be established such that starting of the arc is very slow or even impossible.

Besides this influence of the amount of gas present the assumption of cathode rays emitted by the cathode at the low

voltage under consideration is also supported by the fact that the shape of the tube has a great influence on the starting of the arc. The starting takes place most readily when the anode is placed in a straight line with the cathode. If, on the contrary, the tube is of such a shape that cathode rays would have to change their direction a number of times before reaching the anode the starting becomes difficult. This is especially true when the cathode rays which are supposed to emanate from the surface of the mercury cathode have to impinge on glass walls or walls of similar material before reaching the anode.

Finally, the assumption made explains readily the fact that the starting of the arc in narrow tubes by means of an auxiliary arc is very difficult, and in tubes of a diameter below $\frac{1}{8}$ " practically impossible.

(b) *The Conductivity of the Mercury Vapor Diffusing from a Mercury Arc.*—If in Fig. 1 the arc is started between the electrodes C and B and an e. m. f. is applied to the electrodes B and A, a certain current flows in this latter branch, even when the e. m. f. applied is below the polarization voltage which would correspond to the arc. This current has the following properties:

1. The space in the branch AB possesses unilateral conductivity; i. e., the same e. m. f. being applied, the current in one direction is much larger than in the reverse direction. The current in the direction AB is many times larger than in the direction BA.

2. The current in the direction BA reaches saturation at very low voltage. The current in the direction AB first increases rapidly, as the voltage applied increases from zero on, then increases very slowly, until polarization voltage is reached, at which point there is a sudden transformation into an arc.

3. The current in the direction AB does not only depend on the e. m. f. applied and on the current in the arc CB, but also on the previous history of the branch AB. The current corresponding to the same e. m. f. is different when the e. m. f. is ascending and when it is descending.

The experimental data obtained and the theoretical deductions from them would take too much space and I intend to discuss them in the future in a separate publication.

(Read at the Stated Meeting, held Thursday, May 17, 1906.)

The Value and Design of Water Power Plants as Influenced by Load Factor.

BY DR. FREDERIC A. C. PERRINE.

The load curve of any electric plant varies from hour to hour, from day to day and in any one year from month to month.

These variations are not due to a change in the number or character of the customers for light and power, but to the varying demands of the regular customers from daylight to dark and from season to season.

In any winter day the demand for lighting begins with the needs of the early risers whose habits are fixed by factory whistles and railroad train schedules. At about 6 o'clock the demand becomes the greatest and as the sun begins to show some light the load falls. From 7 to 8 o'clock the load begins to rise again as motors in factories and stores are started when the day's work has begun. From this period until about noon the load remains fairly constant, but between 12 and 1 mid-day the load falls rapidly and the lowest period of the whole 24 hours it reached. At 1 o'clock the load comes on again suddenly to about the amount of the morning load. As the afternoon advances and windows are darkened by the failing light lamp after lamp is turned on at a slowly increasing rate until about 4 o'clock when the load begins to mount rapidly, reaching its maximum at about 6 o'clock. At this time there are lights everywhere, in the office, the factory, the kitchen, the dining room, the living room and the bed room.

Within a few minutes more the load again begins to fall rapidly as the factory is closed and both lights and motors are discontinued. The offices are closed and the janitors have finished their work, the younger children are in bed and the elders have completed dressing and gone to dinner. A dip in the load

is then noted; but it increases again to a considerable extent when the theatres open; after they close a rapid fall is perceptible to a minimum which is reached between 1 and 2 o'clock, after which time only the all-night factories and lighting furnish the remaining load

If readings from the electric measuring instruments have been taken at hourly periods during the day and a curve drawn showing the load on a scale of hours this curve so obtained would be called the "load curve" for that day. The load curve for each day has its distinguishing characteristics. In summer the load would not show a rise in the early morning and in general will be decidedly less in amount during each period of the day, except during the daylight hours, when in any case the power load is the only load served; similarly as we move from month to month the characteristics of the load will change with the changing hours of daylight and work time. From day to day such a curve may be drawn and finally the yearly curve obtained. The term "the yearly load curve" has also been applied to a curve showing the daily volume of the *average* load throughout the year and also the term has been used to describe the curve showing the daily *maximum* load for each day of the year.

For the purpose of this discussion, however, we will confine the term "load curve," whether it be a daily or yearly curve, to the true value of the energy supplied per hour throughout this period.

In a study of the problem before us it is necessary to examine this load curve and describe some of its characteristics. First, we notice that the area of any such a curve represents the total number of kilowatt hours supplied to the load.

Second, that the average load is obtained by dividing the total kilowatt hours by the number of hours, and that having drawn a line across the curve at the height of the average load we see by inspection the hourly variation from the mean load. Finally, we obtain directly from the curve the value of peak or maximum load and the value of the minimum load, as well as the time of day during which the load is a maximum, a minimum, and a mean. With these facts in hand many points in the correct design of any power station are readily determined. Such points are the proper subdivision of units, the value of

overload capacity in carrying the peak, and the value of load for carrying which the machinery should be operated at its maximum of efficiency.

If from our load curve we obtain the value of the maximum load and the average load, the relation of these two is called the "load factor." In other words the load factor is the relation of the load actually obtained to the load which would have been obtained had a load equivalent to the maximum at any one time been carried throughout the period.

As in the case of the load curve this term "load factor" also is applied by different engineers to different quantities.

Some apply the term as it has been already defined, which is actually the only meaning which is really justified by the name "load factor."

But others claim that it is more expressive of the conditions which control the economy of operation in the plant; if it be defined as the ratio of the average load actually supplied to the maximum capacity of the machinery in operation at any one time. This use of the term is based on the assumption that all machinery in the plant not put into operation at some time for carrying the load must be considered as in the station for the purpose of reserve and that the cost of operation is most largely dependant on the capacity of the machinery at any time in operation.

A definition of the term more directly useful in addressing of the problem in this way would be that the load factor is the relation of the average load to the capacity of the machinery in hourly operation, since the maximum station capacity at any time in operation represents a cost of operation in excess of the actual. On the other hand the cost of operation at full load of the machinery which is in hourly operation represents very nearly the true cost of operation.

There are others again who define the "load faction" as the relation of the average load to the total capacity of the station on the ground that the most essential element of cost is the total installation cost.

This latter definition of load factor is always in mind when the value of a hydro-electric station is given flatly in dollars per kilowatt of machinery installed.

But the load curve and the load factor are ordinarily con-

trollable by the business management of any plant by choice of character of load. The various customers of any power plant have each a particular load curve which is controllable only within very narrow limits, but the character of loads vary so greatly that it is possible by choice of customers to control the station load factor. This choice of customers is made to an extent automatic by methods of charging which penalize the undesirable load and encourage that which is wanted.

In attempting to increase the value of a load factor much has been accomplished by supplanting a lighting load by a railroad load. On a little reflection one at once sees that when the factories and offices close the cars run full, and furthermore, the greatest railroad load is in the summer when the lighting is the least.

In the case of a large hydro-electric station these two classes of load represent but a single element in the problem. Factories and industries of many kinds must be supplied. Hence it is necessary to either carefully select the load to be carried in accordance with the character of the plant or else to adopt the character of the plant to the probable load curve or load factor obtainable.

To one who has given even an elementary consideration to the problem of coal economy in a steam plant, the effect of load factor is at once apparent. The guarantees which are made in the contracts for steam machinery, and which are met in the plant tests are not realized as a matter of daily operation, excepting in the case of large pumping plants and steamships. The reason for this is not that there is a trick performed in the tests or that the machinery deteriorates rapidly after original installation, but it is due to the effect of the load factor. Whenever the load factor is unity the full economy realized on the test is also obtained in operation when the management is careful. But when the load factor is less than unity periods are encountered when the load carried is not the most economical and, especially if there are periods when fires are banked, the coal consumption in proportion to the load is increased.

This matter is of such great importance that it is difficult with a load factor of 30% to reduce the coal consumption to less than five pounds per kilowatt hour even though the steam ap-

paratus at its most economical load will operate on less than two pounds per kilowatt hour

This matter of load factor often affects the hydro-electric plant more seriously than the steam plant, though it is more generally true that the adaptation of plan to load factor is more often controllable in the design of the hydro-electric plant than in the design of the steam plant.

When the exceptional case of a unity load factor is encountered and at the same time the streamflow is constant, the plant and load are perfectly adapted to each other. This condition is to be found in certain of the Niagara plants and nowhere else. There the water flow is constant and the load is that of electro-chemical industries whose load is closely controllable.

Where the load factor is less than unity and a stream providing no storage is furnishing the energy, energy is wasted whenever the load is less than the maximum capacity of the stream. On the other hand where sufficient storage may be provided, a load having a factor of less than unity may be served without waste of hydraulic energy. Providing water storage for a variable load is the most direct method in design for attacking this problem.

Certain plants may be designed where the head and storage are simultaneously obtainable, and it is often advisable to sacrifice other elements of design to solve the problem in this manner. For example, the simplicity of plant obtained by the use of a high head has in certain plants already built caused an oversight of the fact that a construction more closely adapted to the condition of loading might have been obtained by changing the location to one of lower head but more than equivalent storage and at a lower cost in proportion to the service to be rendered.

Storage sufficient to take care of a load factor of less than 60% is rarely obtainable in larger plants where the head is less than about one hundred feet for the reason that the quantity of water necessary to store becomes too great to be provided in the available storage basins.

A correlative solution of this problem of design is found in the selection of the load itself.

The problem of design then becomes a problem in determining rates and is one which concerns the engineer as directly as

the design of the power plant itself. No one except the engineer can determine the load factor the plant may economically handle, nor can anyone save the engineer point out to the customer the modifications most readily made in his individual load to enable him to obtain service at the least rate and so obtain for the power plant the desirable load curve. For steam plants this problem has been studied carefully and definite methods are agreed upon for obtaining the highest load factor and the flattest load curve, which is all there is of the problem when using steam, but in the hydro-electric plant the problem and the advisable load curve is different in each case and must be separately solved in each case. This correct solution adds greatly to the value of the plant.

After all has been done that is possible in obtaining the best possible storage and in selecting the most satisfactory customers, it is often the case that there remains a residuum in the problem which may be economically handled only by steam or gas auxiliaries. But a short time ago the presence in any hydro-electric system of steam or gas auxiliaries was considered a confession of weakness in the hydraulic system. Fortunately this false idea is fast losing ground and it is recognized that the best of engineering is shown by their use, and in consequence fine hydro-electric opportunities are being utilized which were previously neglected.

Streams of comparatively constant flow by the installation of steam or gas auxiliaries are enabled to supply heavier loads than would be otherwise possible, though perhaps the most important use is found for auxiliaries in cases where the normal stream flow is very materially reduced during short periods of the year, by reason of special conditions in the water-shed.

No hydro-electric plant should at the present time be studied without considering the use of auxiliary power. Oftentimes such a study will result in the rejection of auxiliaries altogether. Oftentimes the employment of auxiliaries will, by the conditions shown, obviously be postponed to a later date than that of the original installation of the hydro-electric plant. But again, when it becomes apparent that auxiliaries are useful, it is immediately necessary to decide on the type of auxiliary installation most closely adapted to the conditions of water supply and loading. In some cases it is advisable to supply the

constant load by steam or gas auxiliaries, which are installed in such a manner as to obtain the greatest possible economy of operation, and in such cases the variable load will be supplied from the hydraulic installation. In other cases, the reverse is true, and then the problem presented for choice of the auxiliary is determined by ascertaining the plant which can be installed for the lowest capital charge and fuel charge for the load which the auxiliary plant is to furnish. This in some cases results in the use of uneconomical steam machinery, and in other cases in the use of machinery of the highest grade.

From what has already been said, it is quite obvious that the load curve and load factor are both involved in determining the gross revenue from any hydro-electric plant. It is true that in many cases of plants which have been installed, the revenue is based upon an assumed load factor of unity and charge for current made on the basis of the maximum customer's demand. This method of charging requires a rate lower than might be obtained by a different method of charging, since only those customers who can control their load factor to a value close to unity can afford to enter into such contract, and it is only justifiable where no means can be provided for handling a variable load factor in the plant and where sufficient customers for utilizing all the power furnished by the plant can be obtained. In general, the effect of this crude method of charging reduces the possible earnings.

Where it is impossible to find customers whose load factor is high or adapted to the supply, the value of the plant is consequently and correspondingly reduced, since no matter what may be the method of charging, whether on the basis of a rate per K. W. hour or on the basis of the maximum demand, the rate must be figured out in accordance with the type of demand and there is no way of charging which is equivalent to an engineering solution on the problem, which enables the curve of the actual load to be equivalent to the possible supply from the plant itself. An unsuitable load is not necessarily one of a low load factor but is one in which the curve of the load is different from the possible curve of output. A uniform load is unsuitable for a variable stream, whereas a suitable load and in consequence a higher revenue might be obtained from the same

stream if a variable load could be obtained corresponding to the variations of the stream flow.

Where the engineering of both plant and load can make the two load curves correspond exactly, the greatest possible output in revenue can be obtained from the hydro-electric plant, whether this be done by steam or water auxiliaries or solely by the engineering of the business department, in order to make the two curves correspond.

The common method of evaluating a water power plant is to state its cost or value in terms of dollars per unit of capacity, as we say that a plant is worth \$100, \$200 or \$300 per K.W. installed. This method of rating the value of a plant is only suitable where the supply possible from the plant is at a constant rate and the load factor of the customers load is unity.

It is in general very false to reckon the value of a plant upon any other basis than that of its output in kilowatt hours, which is the true method of reckoning cost and determining the relative value of water power and other sources for obtaining power.

It is true that a considerable proportion of the plants already installed are valued solely upon a basis of capacity and that they are charging their customers upon a maximum demand rate, but it is also true that in a number of these very cases an increase might be made in the revenue if a rate somewhat dependent upon the customers load curve were adopted. The maximum demand rate encourages no customer save the one whose load factor is nearly unity, and who, in consequence, may supply his needs from other sources of power upon the best competitive terms. When the problem is so considered we see that the maximum demand rate of charging is a low rate for charging and in consequence the valuation of a plant upon the basis of its capacity alone results in an undervaluation of a large proportion of hydro-electric opportunities. The reason that this is so is that this method of valuation takes no account of the possible load factor or of the cost of power in the particular territory supplied when generated in any other manner.

The true method of valuing a hydro-electric plant is dependent upon its competitive value in the territory, and this requires that it be done upon the basis of the total number of K.W.H., which may be generated and sold.

The competitor of a hydro-electric plant is a steam plant and this steam plant runs at an increasing cost per K.W. hour with a variable load, in consequence any hydro-electric plant capable of supplying a variable load can obtain from that load a higher revenue per K.W. hour supplied than is the equivalent of the minimum stream flow, and often higher than the capacity of the total station and where the load is adapted to the possible output from the plant a more valuable installation is obtained, even though the minimum of the stream flow may be much less than in a corresponding plant, where the minimum flow obtainable is greater, but the load is unsuited to a full use of the stream.

The true method of evaluating any plant, whether steam or electric is on the basis of the K.W. hours of output which is saleable, and in making this statement we should not by any means neglect the fact that a very considerable item in determining the value of a plant is necessarily based upon the intelligence of the management and of the engineer in establishing rates which will obtain a load adaptable to the possible supply. Following the lead of other stations which are operating profitably often results disastrously to hydro-electric installations, when these installations might have been made greatly profitable by a proper adjustment of the loading and charging.

It is much simpler to multiply the rate of greatest possible output by a round number of dollars, but this method gives no idea of what is the true value of the plant. To obtain a value worthy of notice it is necessary to obtain the possible load curve of the customers and from this determine the construction of the plant and its operating cost and then after a similar estimate has been made of the cost by steam or the best other competitive power, an evaluation may be made which is intelligible.

It is not reasonable to develop a hydro-electric station, when a steam or gas station could be built which would supply the same territory at a less amount of cost, but it is also unwise to condemn a hydro-electric development, because the cost per unit of capacity is high, when at the same time it can develop cheaper power than can be done in any other manner.

There is nothing new or revolutionary in these ideas, and they but state the common sense view of the problem, but at the same time the present day usage takes into account only capacity figures with oftentimes added absurdities about "second"

power and "short time" power and "night power," none of which can be marketed under the system of charging proposed.

A recognition of the true method of valuing such plants which is here described would at the same time result in correct figures and would point out to the management as well as to the engineer what must be done to increase its value to the greatest possible figure.

This would result in a true evaluation of the hydro-electric development and result in an increase of what is already a large and profitable industry.

TIN IN SOUTHERN NIGERIA.

During the early part of the season 1904-1905, the officers of the Survey, John Parkinson and H. L. Huddart, discovered deposits bearing tinstone while making a traverse of the Uwet district. In view of the commercial importance of tin, it was considered advisable to examine carefully the stream deposits of this district, in order to determine their richness in tinstone. The district examined lies between Awai-Iku, on the north, the Ekpri-Ibami, on the south, and along the route passing through Akwa-Ibami, Uyanga, Oyja-Ekankpa, Oyja-Nkorimba, and Ofunapa. The deposits met with along this route were panned and examined for valuable minerals, more particularly for tinstone. Eighty-seven concentrates were thus obtained, and, after preliminary examination, forwarded to the Imperial Institute for detailed investigation. Most of these concentrates consist principally of garnet, staurolite and ilmenite; monazite, cassiterite, columbite, rutile, tourmaline, zircon and hornblende are subsidiary constituents, while gold occurs occasionally in traces. Of this series of concentrates, only those from the Akwa-Ibami district are sufficiently rich in tinstone to be of importance from a commercial standpoint.

The impurities in the tinstone concentrates of Akwa-Ibami consist of columbite, garnet, ilmenite and tourmaline, with a small amount of quartz and occasionally magnetite. Quartz can be eliminated by washing; the other impurities, being magnetic, can be fairly completely separated by the electromagnetic methods. In this way, the tin-bearing deposits of Akwa-Ibami could be made to yield a product containing, as a rule, the equivalent of 75 per cent. of metallic tin.

The conclusions to be drawn from this investigation of the stream tin deposits of Southern Nigeria are by no means of a definite character. The best occurrences can only be described as poor, in comparison with the generality of alluvial tin deposits.—*Eng. and Min. Jour.*

Mechanical and Engineering Section.

(Stated Meeting, held Thursday, April 26th, 1906.)

High Pressure Steam Tests of an Injector.BY STRICKLAND L. KNEASS, C. E.

There are few devices connected with the operation of the locomotive that awaken so much interest, both from a practical, as well as a theoretical point of view, as the Injector. A knowledge of its action under different conditions of steam pressure, height of lift and water supply temperature, is useful to the locomotive builder and railroad mechanical engineer, while the relation of its performance to the theoretical formulae for delivery is of interest to the student of thermodynamics. It is therefore pertinent to present the results of a series of experiments covering an unusually wide range of conditions, and indicate diagrammatically the performance with locomotive boiler pressures, as well as the limitations of the Injector in service.

The instrument that was tested is known as the Improved Self-acting Injector, Size No. 10 $\frac{1}{2}$, and embodies certain features which render its study of value, and though the experiments are not exhaustive, yet they cover most of the practical applications; other features which may be classed as minor, are omitted in this paper.

A sectional view of this Injector in its simplest form is shown in Fig. 1. From the delivery tube *c* the other parts are proportioned, and the diameter is 10.5 m/m (0.41") at the smallest part of the bore. The main or forcing steam jet which forces the water into the boiler is 13.34 m/m (0.53") in diameter and the annular area of the lifting nozzle corresponds to a circular opening 8.13 m/m (0.32"). A special feature of the design is

receiving end of the forcing combining tube is considerably below that of the atmosphere, and at times is 20" vacuum, increasing the flow through the lifting tubes. These conditions obtain as the steam pressure rises until the increased discharge of steam from the forcing nozzle requires a greater supply of water than can be obtained from the lifting tubes, so that while the forcing jet is passing the apertures d^{11} , d^{111} , which open into the overflow chamber D, a partial vacuum is produced in the overflow chamber; some of the water in the suction pipe B and water chamber B^1 will therefore be diverted from the entrance of the lifting combining tube b^1 , raise the supplemental inlet valve f^1 and enter the overflow chamber D, submerging the openings of the forcing combining tube. The jet in this tube will then draw the supplemental water supply from the overflow chamber D into the combining tube bb and carry it through the delivery tube c , thus materially increasing the capacity of the injector.

At steam pressures below 120 pounds, the capacity of the lifting set is sufficient to supply the forcing tubes and the supplemental inlet valve f^1 is inactive.

The apertures d^{11} , d^{111} , and d^{1111} in the forcing combining tube bb have a further function, namely, that of free discharge of steam from both nozzles without producing a back pressure in the suction chamber D^1 ; this permits the Injector to restart automatically. Under all conditions of operation, there is a partial vacuum in the suction pipe, for the overflow valve d^1 and its connecting outlet passage are of ample size to permit the free out-flow of exhaust steam with all steam pressures.

The actual form of this injector, as used in service, is shown in Fig. 2, where No. 1 is the delivery tube, No. 2 the combining tube and No. 3 the steam nozzle; No. 42 is the supplemental inlet valve and No. 30 the overflow valve. The operation is as follows: Steam from the boiler is admitted to the lifting nozzle by drawing the starting lever No. 33 about one inch, without withdrawing the plug on the end of the spindle (7) from the central orifice which admits steam to the forcing nozzle No. 3. The discharge of steam from the lifting nozzle exhausts the air and condensed steam or hot water from the suction pipe. When water appears at the overflow, the starting lever No. 33 is drawn back and the injector delivers into the

boiler. At 200 pounds steam pressure about 20% of the total water supply for the tubes is admitted through the supplemental inlet valve No. 42.

The water regulating valve No. 40 is used only to adjust the capacity to suit the need of the boiler, as the automatic adjustment of the water supply to suit all variations of the pressure of the steam by the inter-action of the two steam jets prevents waste at the overflow valve.

During the operation of the Injector as described above, it is assumed that the temperature of the water supply is normal, but when it exceeds that with which the Injector will operate without wasting, the overflow valve No. 30 must be locked, and all subsequent overflow from the tubes will fill the overflow

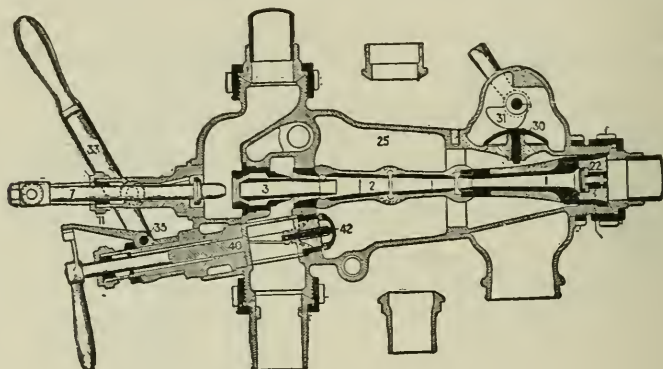


Fig. 2. Service form, lifting injector

chamber and cause an external pressure upon the jet. The highest admissible temperature of the water supply will then be limited by the power of the jet of water when crossing the openings of the forcing combining tube, to withstand the lateral pressure of the contained fluids in the overflow chamber No. 25. The lower the velocity of the jet, the more sensitive it is to external pressure, so that if the openings at the widest part of the tube near the steam nozzle are protected, the jet can then withstand a higher pressure and the temperature of the water supply still further increased.

In the Class K (lifting or non-lifting) forms of this injector, the upper opening of the combining tube near the steam nozzle is protected by a special automatic valve No. 98, shown in

Fig. 3. This injector permits the use of a water supply reaching a temperature of 147° at 200 pounds steam, which is 22° higher than the limit of the form shown in Fig. 2.

The high pressure tests were made with steam taken from a 300 H. P. Babcock & Wilcox boiler, capable of carrying 300 pounds to the square inch; tests at the lower pressures were made with the same Injector and tubes, connected to a low pressure boiler in order to avoid superheating the steam by excessive throttling. A separator was placed in the steam

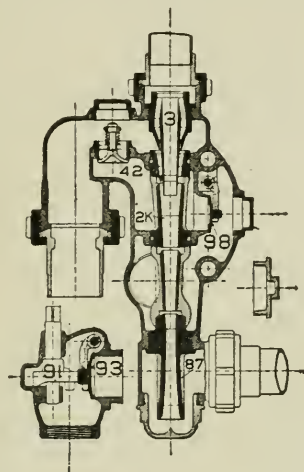


Fig. 3. Class K. Non-lifting form

pipe, lagged and carefully drained. The water in the supply tank between point levels, was weighed and continually rechecked; all thermometers and gauges were accurately calibrated; observations and readings were taken by three operators. As soon as a test was made, the result was plotted on a temporary diagram to determine its correspondence with previous operations; if found to vary from the general trend of the curves, it was repeated and errors thus eliminated as far as possible. In the final diagrams, the curved lines connect the individual observations and are extended above and below the limit of experiments according to the general tendency of the established curves. In each diagram the abscissas indicate the gauge steam pressures per square inch and the vertical ordinates, gallons per hour, degrees Fahrenheit, etc.

No 10½ SELF-ACTING INJECTOR
MAXIMUM AND MINIMUM CAPACITIES

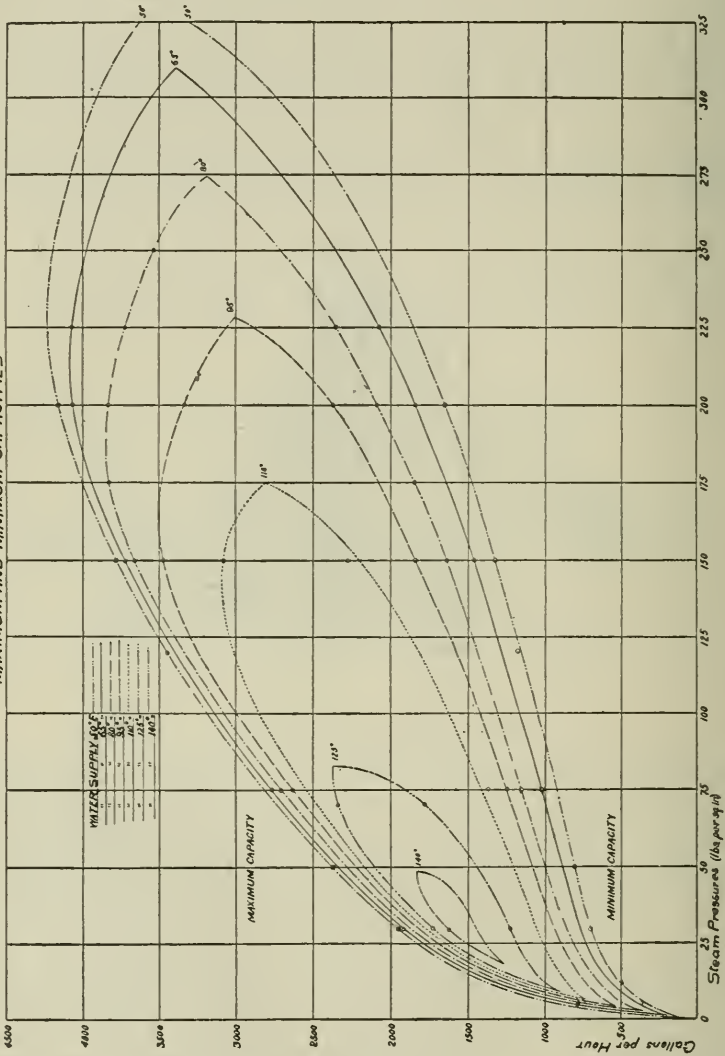


Diagram 1

No 10½ SELF-ACTING INJECTOR

LIMITING AND OVERFLOWING TEMPERATURES 25 INCHES LIFT



Diagram 2

The points on the curves at which the experiments occur are denoted by small circles.

Diagram I shows graphically the maximum and minimum capacity at steam pressures ranging from two pounds per square inch to 325 pounds, when the temperature of the water supply is 50°, 65°, 80°, 95°, 110°, 125° and 140°; the Injector in each case operating with the overflow valve free to open, to permit automatic re-starting. The vertical scale indicates gallons per hour from 0 to 4500, and the horizontal scale, steam pressures from 0 to 325 pounds.

From diagram I can also be obtained the range of capacities for any desired steam pressure and water supply temperatures, by subtracting the values given by the curved lines; for example, when the boiler pressure is 200 pounds, and the water supply 65°, the maximum capacity is 4,068 gallons per hour and the minimum 1,846, giving a range of 2,222. The overflowing temperature is that point at which no regulation of the water supply will prevent the emission of drops of water at the overflow; it therefore corresponds to the temperature at which the maximum and the minimum capacities coincide; this is indicated by the pointed junction of the maximum and minimum lines on the diagram for any given condition; for example, at 275 pounds boiler pressure, the overflowing temperature is 80°, at 175 pounds, 110°; points not shown on diagram may be interpolated, but are more clearly shown in diagram II, where the temperature tests are specially plotted.

The results shown on diagram I are of much interest and clearly show the remarkably high capacities given by this form of Injector at steam pressures varying from 175 to 250 pounds. The upward course of the line of maximum capacities corresponds closely to the theoretical line for perfect efficiency, based upon the well-known formula for efflux of water, $V = 2\sqrt{gh}$, the divergence being greatest at the high pressure. The tests were made with a single set of tubes for all pressures, operating as low as 2 pounds steam and tested as high as 250 pounds; the extensions of the capacity lines show the performance at still higher pressures.

Diagram II shows the limiting temperatures of the water supply. First, the overflowing, or maximum temperature of water with which the Injector can start automatically, and second, the

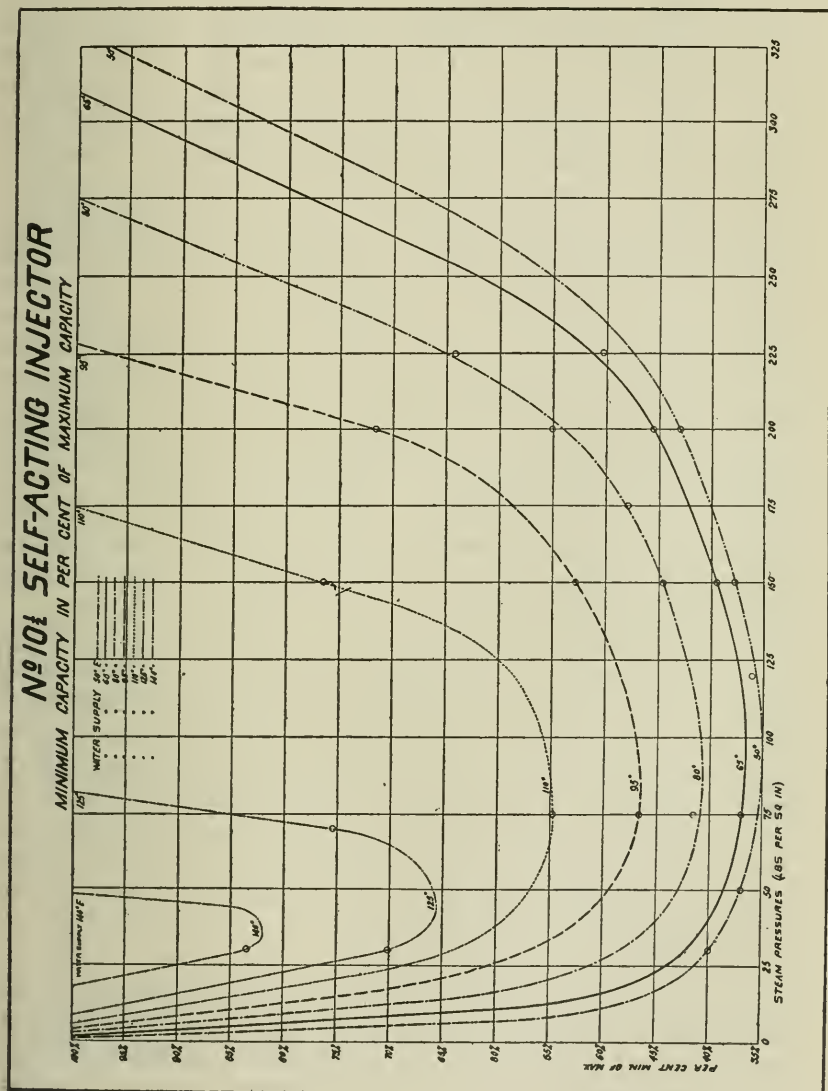


Diagram 3

highest temperature of water supply with which the Injector can operate.

In service, when the temperature exceeds that at which the water appears at the overflow, the overflow valve No. 30 is forcibly held to its seat by rotating the cam No. 31, by means of the lever No. 34, thus preventing the escape of water or steam. The temperature of the water supply may then be raised to the upper limit without interfering with the action of the Injector. When the boiler pressure is 200 pounds, the limiting re-starting temperature is 104° , while the maximum admissible temperature is 125° . As indicated on the preceding diagram, the most efficient steam pressure for warm water is about 32 pounds, when the two limits are 145° and 147° . The peculiar offset to the curve between 75 and 125 pounds is due to the action of the supplemental inlet valve, which permits an additional supply of water to enter the forcing combining tube without being subject to the heating action of the steam from the first or lifting nozzle; this supplemental supply is drawn from the suction pipe through the overflow chamber (25) containing the forcing combining tube (2) and into the opening in that tube instead of entering the mouth of the combining tube with the main supply.

The above limits of temperature are sufficient for all ordinary requirements, but the Class K form of the self-acting Injector, which has already been referred to in the description of Fig. 1, is designed to meet still more severe conditions. The upper dotted line shows the capabilities of this Injector, which exceed the limits of temperatures of the usual self-acting form by 20 to 28° , between 150 and 250 pounds steam pressure. At 200 pounds, it can lift and deliver to the boiler when the water supply is 147° Fahr. and 135° at 250 pounds pressure. The non-lifting form is shown in Fig. 3.

Diagram III shows graphically the wide range of the injector by expressing the minimum capacity in terms of the maximum. The horizontal scale indicates steam pressures from 0 to 325 pounds, and the vertical scale percentages from 35 to 100. As the top line of the diagram is 100%, it shows the extreme limit of pressure for any given temperature of water supply and corresponds to the pointed intersection of diagram I, while a point on any curved line gives the definite

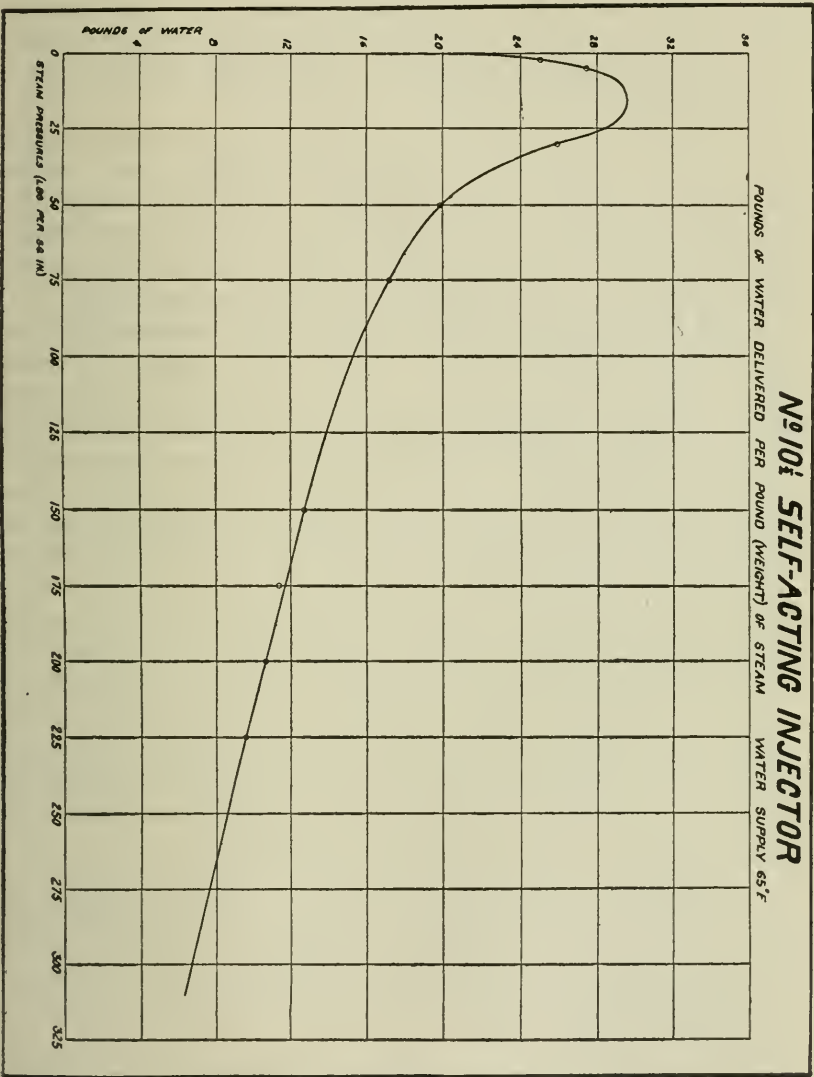


Diagram 4

value of the relation between two points on any vertical line for the corresponding maximum and minimum lines of diagram I. For example, at 275 pounds steam, the minimum capacity is 100% of the maximum at 80°, as shown by the overflowing temperature in diagram II, or the pointed intersection of the 80° line of diagram I.

The widest range is obtained, as should be supposed, with coldest water, namely 50°, and is at 100 pounds steam, when the minimum is 35% of the maximum. At modern locomotive boiler pressure, 200 pounds, water supply 65°, the minimum capacity is 45 $\frac{3}{10}$ % of the maximum, giving an actual permissible variation of the capacity of 2,222 gallons per hour.

The mechanical efficiency of an injector is measured by the ratio of the weight of supply water to the weight of steam used. This ratio is shown in diagram IV, where the vertical scale represents pounds of supply water delivered per pound weight of steam, and the horizontal scale, gauge pressure in pounds per square inch. As was noticed on the previous diagrams, the higher pressures do not show the action to be as effective as at low steam. It is probable that with an ideal injector, or one in which the entering areas of water and steam could be modified to suit every variation of pressure, the curve on diagram IV would extend its parabolic tendency upward until it approached tangency with the vertical ordinate of 0 pressure. The values shown, however, are exceptionally good, and indicate a high efficiency for this kind of steam-operating device. At 200 pounds pressure, water supply 65°, 10.7 pounds of water are drawn from the supply tank and delivered for each pound weight of steam taken from the boiler.

In conclusion, it may be said that the complete record of tests, as shown on the diagrams, indicate an unusually efficient Injector through a wide range of conditions. The same set of nozzles were used in all tests, from two pounds steam pressure to 250 pounds, a far wider range of pressures than would be required in practice.

Superheated Steam in the Power Station. *

BY ARTHUR S. MANN.

Many questions in regard to the use of superheated steam can be answered mathematically by reference to some of the older laws usually applied to the behavior of water vapor. There are, however, questions of a very practical nature which, while they may or may not fall actually into the category of mathematical problems, are of vital importance in determining the practical advantages in the use of high temperatures.

A portion of any saving to come from the adoption of superheated steam for power generation purposes will depend upon the ease or difficulty encountered in making and in handling it in a steam station. Laws governing the generation and subsequent action of saturated steam are understood. There are some features in the action of superheated steam, however, for which there may be a perfectly plausible and scientific explanation, but which are in a sense unexpected and which can be provided for in a practical way without a complete analytic explanation provided the facts are understood; the mere knowledge of such facts will make it possible to guard against error in design of steam chambers and piping systems.

These paragraphs will relate some of the experiences met in a plant of 8000 boiler horse power, generating steam of 185 pounds pressure and 200 degrees F. superheat.

The superheaters are a part of the boilers. There are three banks of tubes in a complete unit which make up the heating surface, and the middle one of these banks forms the superheater.

The water tube heating surface measures 4000 square feet in area and the superheating tube surface 1700 square feet. The stokers are of the underfeed type and the air supply comes to the fire under pressure.

*Read by title.

The furnace temperature is about 2400 degrees F., and the temperature of the furnace gases is about 900 degrees F. when they encounter the second or superheater bank of tubes.

With steady fires and with a boiler steaming at normal rating the superheat is very close to 200 degrees F. In one boiler trial having a feed temperature of 118 degrees F., the superheat was 205 degrees F., the boiler rating being 102 per cent., that is 2 per cent. in excess of normal capacity, and other trials have varied but slightly from these results.

The gases leaving the superheater bank have a temperature of 615 degrees F., and at the uptake this temperature has fallen to 445 degrees F. or 135 degrees below the temperature of the outgoing steam.

When one of these boilers was first started up it was felt that great care should be taken to avoid overheating the superheater tubes. Provision was made for flooding the surface exposed to the gases and the superheater was filled full of water and gradually drawn down until it was filled entirely with steam as the fires gained in temperature and steam was raised so that there was a flow through the tubes. It is well nigh impossible to injure superheater tubes when boilers are put in service in this way. There is a disadvantage, however, in that there may be a deposit of very dirty water in the superheater tubes and the ability to start in a simple way is to be desired.

It was found on trial that it was unnecessary to flood the superheater in starting new fires and that the tubes and joints would withstand any stresses put upon them provided the fire was started slowly, perhaps a little more slowly than would be considered safe practice with a regular saturated boiler. Starting with a dry superheater with slow fires has been proven to be safe practice and no trouble whatever has been experienced from this method.

The superheater tubes are heavy wrought-steel and are weldless. Very little trouble has been met in the care and management of the boiler and superheater. Some of the tubes have been re-rolled after the boiler was put in service; but in no case has a tube been re-rolled more than once and the boilers have been in use about two years. Not a single tube has been taken out or been injured in any way.

The degree of superheat is fairly uniform for moderate

changes in the amount of steam delivered. The hotter the fire, the hotter the gases about the superheater tubes; but at the same time more steam is passing through the superheater tubes and there is more substance to absorb heat. During a day's run the temperature will not vary more than 40 degrees, provided the feed water has a regular temperature. When the fires are cleaned, however, and there is no steam flowing through the superheater tubes, the steam that is there becomes hotter, averaging thirty degrees above the maximum of the day.

It is possible by forcing fires to increase the degree of superheat to 320 degrees F., giving a final temperature of 692 degrees, and even at this temperature there is no trouble with the superheater though the gases entering the superheater bank are well on to 1200 degrees in temperature.

It has been found that it is possible to have superheated steam and water in the same vessel. This is true even when every opportunity is given to steam to pick up the water and diminish its own superheat.

The superheater is made up of two horizontal drums about eight feet apart, one placed almost directly over the other with two-inch tubes extending from the lower to the upper. Steam enters the upper drum, makes two downward and two upward passes between the drums and leaves the upper drum to go to the steam system.

There is no deposit of water in the lower drum while the boiler is making steam. If, however, the boiler stops steaming and the fires are held in check long enough to allow the furnace gases to cool down, there is a deposit of water in the lower superheater drum. If this water is allowed to accumulate, there is a very considerable amount to be dealt with in the morning, 4" or 5" along the bottom of the drum perhaps.

When the fires are brought up again the outgoing steam is superheated in a very short time fully up to the regular average; but the water in the bottom drum is not absorbed by the hot steam sweeping over it. The surface of the water being some twenty square feet in area, the steam superheated on an average of 100 degrees passing over it at the rate of about 3' per second, it would appear that this whole volume of water should be taken up and made into steam in less than thirty

minutes, particularly as the water itself is at the boiling point, or very near it. This water is not taken up by the steam however. It lies in the bottom of the drum until it is drawn out through a drain pipe.

Even though the rate of travel of the steam over the surface is slow, there is a decided tendency of the steam to pick this water up in slugs and carry it as water over to the steam pipe and into the steam ports and passages; and so far as it has been possible to observe, there is very little tendency to evaporate this water. It collects until there is an appreciable volume and then it is delivered in a body with the steam current.

As a consequence of this action, steam pipes, all low points and pockets in a system intended to convey superheated steam, must be drained as carefully as if the same system were to be used for saturated steam. It will not do to depend upon the supposed readiness of superheated steam to absorb water as it passes above the water surface.

It is not intended to give the idea that superheated steam will of itself deposit water as it travels through a pipe; but if the water is there it will not be absorbed gradually until it has all nicely disappeared. It is picked up in slugs and there is the same danger from water hammer that is met with in saturated steam pipe systems.

It would appear necessary to conclude that the fact that water is known to be present in a vessel does not preclude the possibility of there being superheated steam in contact with it.

The friction of superheated steam within a pipe appears to be greater than the friction of saturated steam. It has been found economical to give the steam high velocity because of the relatively low radiation loss and, though the actual drop in pressure is relatively larger, it may not be a mistake to submit to the loss of pressure from the boiler in order to avoid radiation losses from the pipe system. In the plant above described the velocity is about fifty feet per second through a system complicated by many elbows.

The question of pipe covering is a very important one, as the temperature difference, which is a factor contributing toward the loss in pipe radiation, is over 60% greater at regular loads and 90% greater at overloads, so that roughly there is 60% greater chance for loss than would be met under like condi-

tions with saturated steam. It has been found a money-saving plan to use covering 2" thick on saturated steam work. After careful calculations had been made a thickness of $4\frac{1}{2}$ " was chosen for the plant under consideration and when this covering was put on, great care was used to make good joints between covering sections, all possible leaks through covering and between covering and pipe walls being stopped up.

This thickness of covering was applied to pipe and flanges alike, the covering forming a compact body from end to end. The covering over the body of the pipe is finished with a canvas jacket; but this canvas is not carried over the flanges because of the fire risk.

In laying out a system of pipe particular attention must be given to provision for expansion of long lines. This is true of lines conveying saturated steam and more than ever true with steam at 580° F. The expansion is about double what it is in an ordinary pipe system, 3" to every foot being the average for covered pipe and branches 100' from an anchor point must be long enough to give 3" safely if the main is put up cold and is cut to exact length.

It is not difficult to find a form of steam pipe joint which will be tight for superheated steam at these pressures and temperatures under discussion. It may not overstate the case to say that any good joint that would be adapted for saturated steam of equal pressure will hold superheated steam. The question of gaskets, however, must be considered carefully, and it is extremely easy to be deceived by the action of a gasket. Out of seven sorts of gaskets not one has been proven a failure during a three-months' trial. The real test of a gasket, however, is found in the number of times which it will successfully go through the operation of resisting the passage of water of condensation and whatever water may come from the lowering of pressure and drawing down the main and through stagnant steam in the pipe for a more or less extended period. What is really wanted as a packing that will always act in a pre-determined way under certain stated conditions.

Certain metal joints have served the purpose for over a year and there are joints in the station under discussion that have stood for two years, undergoing such changes in temperature a great many times. It frequently happens, however, that

a pipe joint adjacent to one of these joints which have stood so well, both provided with metal gaskets, will fail in three or four months and be unreliable in every way.

While the metal gasket is not to be condemned, the success of some of the sheet packings has been so marked that for general work they may be safely chosen. All of the more successful sorts have a great deal of asbestos in their make-up; in fact, there are four kinds of asbestos sheet packing in use at the station now and there is but one failure charged against these four. It seems safe to say, that if the joints face up fair and are provided with plenty of good stout bolts and the flanges themselves are heavy, that no great difficulty will be experienced in making sound joints.

The difficulties met in the handling of superheated steam are not severe, are not of a character that cannot be overcome, and the additional expense, over and above that met in a saturated steam plant, is very trivial.

A GROWING INDUSTRY.

The lapidaries of the United States are growing in skill, according to the statement of Mr. George F. Kunz, of the United States Geological Survey, in his report on the production of precious stones in 1905. No better lapidary work has ever been done at any period than in the last two years in this country.

The intricate Louis XV and Louis XVI designs in jewelry have been the fashion. Aquamarines, tourmalines, peridots, kunzites, and amethysts have been cut and polished not only in round designs but in oblong, hexagonal, octagonal, marquise, and pear-shaped forms. There has been especial preference for many of the larger stones. Never have aquamarines, tourmalines, and amethysts been sold in such profusion.

IMPORTATION OF CRYOLITE.

Considerable quantities of the mineral cryolite are imported from Greenland each year for use in the manufacture of sodium salts. The quantity of cryolite imported during the year 1905, according to a report made by Mr. Edmund Otis Hovey, of the United States Geological Survey, was 1600 long tons, valued at \$22,482, as against 959 tons, valued at \$13,708, in 1904, and 7708 tons, valued at \$102,879, in 1903.

In the processes of manufacture calcium fluoride results as a by-product, and is saved to be sold for use as a flux in open-hearth steel furnaces in the same manner and with the same results as the natural calcium fluoride or fluorspar. The quantity of the artificial fluoride made depends, of course, upon the quantities of cryolite treated, and is said to be usually from 3000 to 4000 short tons per year.

Section of Physics and Chemistry.

(*Stated Meeting, held Thursday, February 15th, 1906.*)

Weather Forecasting From Synoptic Charts.

BY PROFESSOR ALFRED J. HENRY.

U. S. Weather Bureau, Washington, D.C.

Modern weather forecasting by synoptic charts is based on two well established facts, viz., (1), the general eastward drift of the atmosphere in temperate latitudes in the northern hemisphere, and (2), the close relation that subsists between the weather and the distribution of atmospheric pressure. These two facts are based on accurate observational data, and may be considered as the ground work of all scientific weather forecasting.

For the preparation of a synoptic chart two things are necessary, first, simultaneous meteorological observations over as large an area as possible, and, second, immediate collection of the observations at some central point.

In this country simultaneous meteorological observations are made twice daily and immediately telegraphed to Washington. To these are added by comity of exchange similar observations made in the Dominion of Canada. The total area represented in the field of observation is not far from 4,000,000 square miles, or about one-fiftieth of the area of the globe. This area is less than one-half of the land surface that can be controlled by the Russian Empire, in whose realms are found one-seventh of the total land area of the globe. This fact is pointed out merely to correct the impression that the natural opportunities for the development of a weather service on this continent are unsurpassed.

The Observations.—The following-named elements are observed: (1), the air pressure, (2), the air temperature, including the highest and lowest readings of the thermometer in the

twelve hours preceding the observation, (3), the direction and force of the wind, including the maximum velocity of the wind since the last observation, (4), the state of the weather and the sky, that is to say whether it is fair, raining, snowing, or sleeting, and whether the sky is clear, partly cloudy, or cloudy, and whether fog or haze is present. If clouds are present the kind and direction of motion are recorded. The amount of precipitation is also recorded, and the dew-point and relative humidity are determined. The full observation made at Washington, D. C., on the morning of February 15, 1906, is here given:

Barometer, reduced to sea level.....	30.29"
Temperature of the air: dry thermometer.....	19°
wet thermometer.....	17°
Max. (last 12 hours).....	46°
Min. " " 	18.8°
Wind: direction, northwest, and velocity in miles.....	20
max. velocity in last 12 hours, and direction N.W.....	31
Rain in last 12 hours.....	Trace.
" 24 " 	Trace.
State of weather.....	Clear.
Clouds, in tenths.....	1
kind, ...	Alto-stratus.
direction from.....	West
Relative humidity.....	69%

Since the height of the barometer varies with altitude and temperature the barometric readings are reduced to sea level and a uniform temperature of 32°, in order that they may be comparable *inter se*. A small correction is also applied to reduce the barometric readings to standard gravity. The next step in the preparation of a synoptic chart requires that the observations be telegraphed to a central point. For obvious reasons it is not practicable to forward the observations over the telegraph wires in full, as given above. Recourse to cipher codes is therefore necessary. The code now used by the United States Weather Bureau was devised by General A. W. Greely, the last of the military chiefs of the weather service. The code takes cognizance of even numbers only; for this reason the weather reports on all maps and bulletins always appear in even numbers. The code is a simple arrangement of consonants and vowels of the alphabet in a series of words so as to be readily translatable at sight. Thus the word "Dundee," according to

its position in the report, may mean, barometer 30.20 inches, temperature 24° , or a northwest wind with clear weather and maximum temperature of 24° . The significant combination of letters in the word are, Du=20; de=24. The values from 10 to 90 are obtained by the use of consonants; b=10; d=20; f=30; g=40; m=50; n=60; r=70; s=80; t=90. The unit figures are supplied by the vowels: a=2; e=4; i=6; o=8; u or y=0. Enciphering the observation by General Greely's code the observation takes the following form: Washington—doughboy—hyky—sumner—dubois—pitfall. The particular advantage of this code is found in the rapidity with which it can be deciphered and the economy in telegraph tolls that results from its use.

Collecting the Observations.—After the observations are enciphered the cipher report is immediately filed at the local telegraph office for transmittal to Washington. In order to expedite the transmission of weather reports to Washington absolute control is secured for about an hour and a-half of a number of trunk wires radiating in different directions from Washington as a center. A brief description of the method of sending and receiving reports over one of these trunk lines will suffice to illustrate the general plan of collecting and distributing weather reports. It should be remembered that the larger local offices of the Weather Bureau outside of Washington, D. C., must be supplied with daily reports for local use.

The Portland, Me., trunk line, so-called because its northern terminal is in that city, passes through the cities of Boston, Providence, Hartford, New Haven, New York, Philadelphia, Baltimore, and terminates in Washington, D. C. At 8 o'clock each morning the weather report of the Portland station is sent over this wire and is copied, not only in Washington, but also in all of the other above-named cities. As soon as the Portland operator has finished sending his report, the Boston operator follows with his report, and in like manner each operator on the line sends his own report and copies those sent by the other operators. When the local reports on the Portland wire have been received in Washington the telegraph operator at that point transfers them to other trunk wires in that office and receives in return reports that have been received from other portions of the country. These he sends over the Portland wire to the stations on that circuit, the complete receipt and transfer of

all reports usually being accomplished in an hour and a-half, depending on the condition of the weather and its effect on telegraphic communication.

Preparation of Synoptic Charts.—As the reports come over the wires they are translated and transcribed on a set of blank maps of the United States and outlying territory. One principal and three auxiliary charts are made. The entries on the principal chart are as follows: (1) the temperature; (2) the air pressure; (3) the direction and velocity of the wind; (4) the amount of precipitation; (5) the state of the weather.

The three auxiliary charts show, (1) the changes in air pressure that have occurred in twelve and twenty-four hours, also any marked rise or fall in pressure that has been observed within the two hours immediately preceding the observation; (2) the maximum and minimum temperatures for each twenty-four hours, the temperature at the hour of observation and the changes therefrom that have occurred in twelve and twenty-four hours, also the departure of the temperature at the time of observation from the seasonal average; (3) the amount, kind, and direction of clouds. Two classes of clouds are distinguished, viz., upper and lower.

Thus it will be perceived the weather conditions prevailing at the same moment of time at the various stations throughout the field of observation have been translated into numerical expressions and symbols, the latter forwarded to a central point and there spread upon blank maps. The next step is to draw lines of equal pressure and equal temperature, since by this means the eye quickly perceives the salient features of the chart and the changes that have taken place since the last observation. Figure I shows the weather map on the morning of December 24, 1904, with the barometer lines (isobars) drawn thereon. The figures entered on the left of the circle indicate the temperature, pressure, wind velocity, and precipitation in the order named, reading from top to bottom. The direction of the wind is shown by the arrow passing through the circle, the condition of the sky as to cloudiness is indicated by the amount of shading. If the sky is clear the circle is not shaded. If rain is falling at the time of observation that fact is indicated by the letter R inside of the circle; if snowing, by the letter S. The isobars join places having the same pressure and are drawn for every tenth

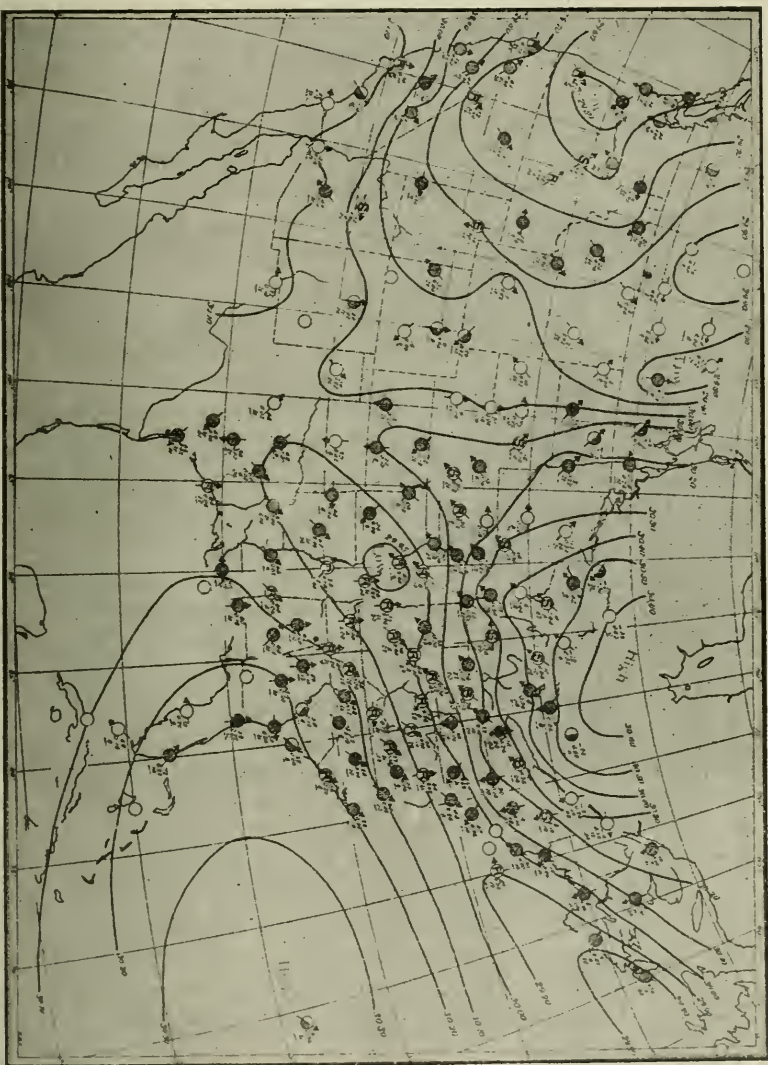


FIG. 1. Weather conditions December 24, 1904, A. M.

of an inch difference in pressure. Thus on the map above-mentioned it will be seen that pressure is high, 30.60 inches, immediately south of the Hudson Bay region, and that it diminishes thence to the Ohio Valley, where it is about 30.00 inches, increasing again toward Bermuda at which point it has risen to 30.36 inches.

In like manner places having the same temperature are joined by lines (isotherms). In the map under consideration the isotherms have been omitted for the sake of clearness.

The map is completed by marking the word "High" about the center of the region of highest pressure and the word "Low" in the center of the region of lowest pressure.

The Terms High Pressure and Low Pressure Defined.—The terms "high pressure," or "areas of high pressure," and "low pressure," or "areas of low pressure," have a special significance in modern weather forecasting. As was stated at the beginning of this paper the character of the weather is closely related to the distribution of atmospheric pressure; if, therefore, the distribution of atmospheric pressure on any certain day can be accurately foreseen a forecast of the weather would follow quite easily. Shortly after the barometer was invented it was found that rain fell more frequently with a falling than with a rising barometer, and that the probability of rain was greater when the barometer stood below 30 inches than when it stood above that figure. Instrument makers were prompt to take advantage of the facts thus observed and to mark opposite certain readings of the instrument the words fair, rain, changeable, etc. Whoever observes the barometer attentively will soon discover that it sometimes rains when the instrument stands at "fine" and that fair weather prevails at times when the glass indicates rain and storm. Since the making of synoptic weather charts was begun it has been possible to verify the belief of that celebrated burgo-master Otto von Guericke, of Magdeburg, viz., that there was evidently some connection between the weather and the rising and falling of the barometer. Synoptic charts gave at once a very greatly enlarged view of the natural processes involved in weather changes, and it soon became apparent that the weather at any point was almost wholly controlled by the eastward movement of areas of high pressure and areas of low pressure. It was also observed that the state of the weather at any point

depended more upon the position of these travelling areas of high pressure and low pressure with respect to each other than upon the actual reading of the barometer at that point. Thus it has been found that in the eastern part of the United States precipitation will begin with the barometer at 30.50 inches, provided the area of high pressure is to the northeastward of the area of low pressure. On the other hand precipitation seldom or never occurs in the eastern part of the United States, no matter what the barometer reading is, provided the area of high pressure is to the westward, say over the Ohio Valley, and the area of low pressure is passing off to sea along the Middle Atlantic Coast. The point of novelty in the modern method of weather prevision lies in the attempt to forecast the distribution of pressure that will prevail at the end of a specified period, say thirty-six to forty-eight hours in advance. If this can be done both the wind and the weather can be successfully forecast. The pressure distribution at any moment of time consists in a series of highs and lows encircling the globe with their maximum development in the temperate zones. For the purpose of this lecture it will be unnecessary to examine closely into their structure, suffice it to say that the wind circulation and the weather experienced in an area of high pressure is diametrically opposite to that which prevails in an area of low pressure. In general the chief characteristics of a high are (1) a central region of high pressure from which pressure diminishes in all directions; (2) clear skies with temperatures somewhat below the seasonal average; (3) light winds which blow clockwise around the periphery of the high. In short the high is indicative of clear, dry, cold weather. The low on the other hand is indicative of cloudy, moist, warm weather with strong shifting winds blowing contra-clockwise around the central region of lowest pressure. A clear understanding of the wind circulation around an area of low pressure and the general weather conditions that attend the passage of one of these atmospheric disturbances across the country is of very great importance. The diagram below, Figure 2, has been prepared to aid in the understanding of these phenomena.

The direction of the wind is shown by the small arrows in different parts of the diagram. These, it will be noticed, are disposed about the center of the storm (the inmost oval marked

"Low") in a rather orderly system. The wind does not blow directly toward the center, but rather spirally about it, as was discovered a little more than half a century ago. In the southeast quadrant the winds have a general southerly direction. In the northeast quadrant easterly winds prevail, while in the northwest and southwest quadrants the winds are mostly northwest to west. An observer stationed in lower Michigan at the point marked "A" will have fresh easterly winds, shifting as the storm center approaches him around to the south by

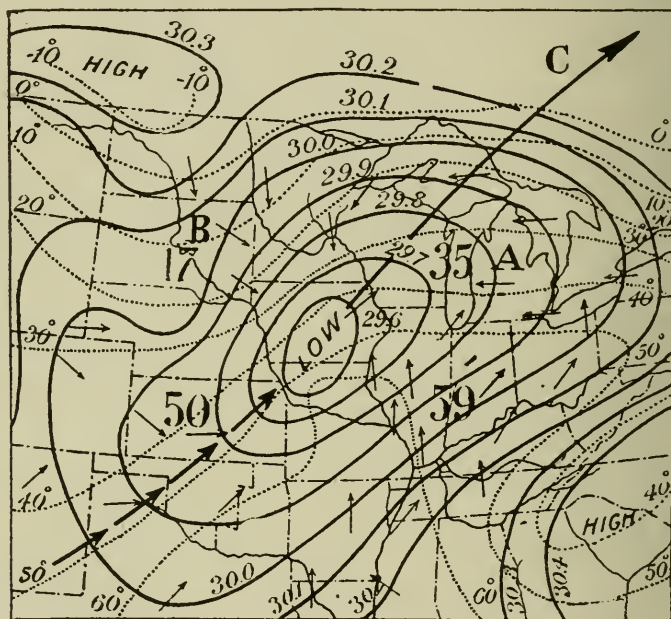


Fig. 2. A typical winter storm, showing wind circulation, isobars and isotherm.

way of southeast, and as the center passes him shifting still farther to the west or northwest.

This is what is meant by "shifting with the sun." On the other hand, an observer in South Dakota at the point marked "B" first experiences a wind from the North, and as the storm center approaches and passes him the wind backs to the west by way of northwest, and this is the meaning of the term "shifting against the sun, or backing." The weather experiences in the two locations, A and B, will differ as regards both temperature

and precipitation. At station A the temperature will rise, and it will continue high until after the center of the storm has moved, say to C. With the shift of the wind to the northwest the temperature will begin to fall, and the downward tendency will continue for twelve to twenty-four hours. The observer at station B will experience cold weather from the start, but the fall in temperature will not be quite so great as at station A. At station A the storm will begin with rain, turning to sleet and snow as the center passes and the wind shifts to a westerly quarter. At B the precipitation will be mostly in the form of snow.

If the diagram be divided into four equal parts by lines passing east and west and north and south through the word *low*, and the average temperature for each part or quadrant of the oval figure be calculated the result will be as follows: for the northwestern quadrant, 17° ; for the southwestern, 50° ; for the southeastern, 59° ; and for the northwestern, 35° . The distribution of temperature is also shown by the dotted lines (isotherms). In the upper left-hand corner the temperature is 10 below zero (-10); between that line and the one next below, the temperature ranges from 10 below zero to zero, and so on until the lower left-hand corner is reached, where it will be noticed the temperature is 60° above zero. On the lower right-hand corner the temperature is only 40° above zero. So far as temperature is concerned, therefore, it is to be noted, that the right-hand* side of an area of low pressure is warm and the left cold.

The various steps leading up to the actual making of weather forecasts have now been sketched. It has been shown that the weather conditions prevailing at a given moment of time are carefully recorded and reported by telegraph to a central point; that they are there spread upon skeleton maps of the region in which the observations were made; that the areas of high and low pressure, respectively, are next located; and finally that it is the eastward movement of these shifting centers of high pressure and low pressure that controls to a great extent the weather experienced from day to day. It is evident, therefore, that the problem will be solved to a great extent whenever the course

*NOTE I.—A person standing in the center of a storm, facing in the direction in which the storm is moving, will have the warm side on his right hand and the cold side on his left and in the rear.

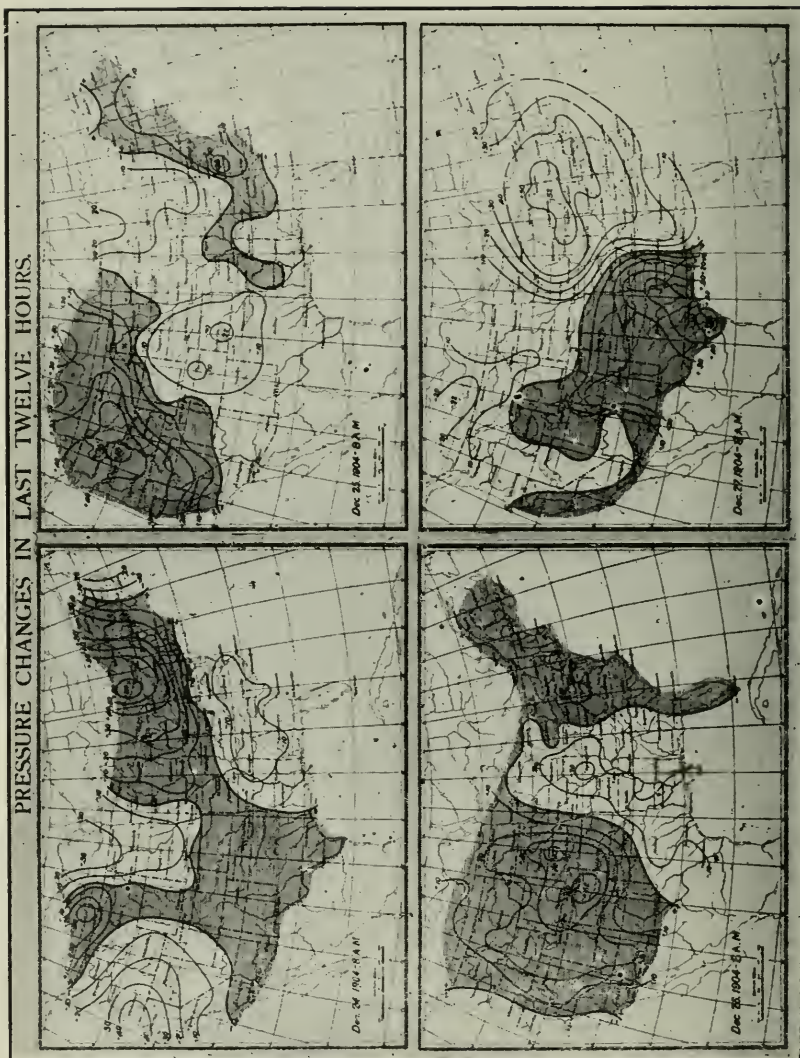


Fig. 3. The unshaded areas represent areas of falling pressure; the shaded areas rising pressure. The amount of rise or fall is given in hundredths of inches at the end of the lines.

and rate of motion of the highs and lows can be accurately forecast.

Forecasting the Paths of Highs and Lows.—The importance of an accurate forecast of the path of a low to within at least one hundred miles is well illustrated in the case of storms approaching Lake Superior from the eastern Rocky Mountain slope. If, for example, the center of the storm passes northeastward over the western end of the lake the winds over the eastern end will set in from the southeast and vessels sailing westward will shape their course accordingly; if, however, the storm should pass northeastward over the northern end of Lake Michigan the winds over Lake Superior will set in from the northeast and drive vessels toward a rocky and dangerous coast.

One of the results of many years observations has been to fix with a fair degree of accuracy the probable path of atmospheric disturbances wherever located. The knowledge thus gained is mainly useful in that it prevents the forecaster from assigning an impossible course to any particular storm. A knowledge of the most probable path of storms is also useful in cases where the influences which usually control their movement give negative results. It is then advisable to expect an increase in energy in the next twenty-four hours and to assign to the storm a normal course for the time and place.

The probable course of each high and the corresponding low or lows, for there may be more than one low, depending on or controlled by a single high, must be determined, not from average conditions, but by the actual conditions as portrayed by the maps in hand.

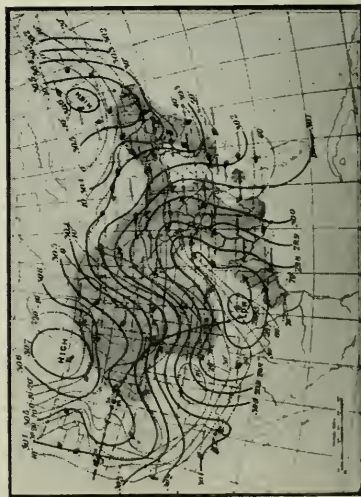
It is extremely difficult to convey a clear idea of the mental operations that are concerned in forming a conclusion as to the probable course of an atmospheric disturbance. In general the forecaster considers the form of the disturbance as shown by the general trend of the isobars, the direction in which they run, whether north-south or east-west. Attention is also given to the surrounding pressure distribution and especially to the changes that have occurred in pressure since the last observation. Some idea of the rapidity and extent of pressure changes may be had from the accompanying chart of twelve-hour pressure changes on four successive days in December, 1904. The rate of the eastward drift, whether fast or slow, the tendency of



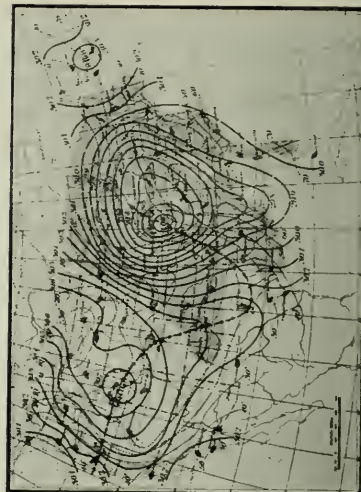
Saturday, December 24, 1904 8 A. M.



Sunday, December 25, 1904—8 A. M.



Monday, December 26, 1904—8 A. M.



Tuesday, December 27, 1904—8 A. M.

Fig. 4. Illustrating the movement of a North Pacific coast storm across the continent.

the centers of activity to shift from northern to southern circuits, the geographic position of the disturbance, the season, and indeed other details enter the problem.

In first approaching the subject of determining the paths of highs and lows the lay mind generally endeavors to reduce the seemingly endless confusion of pressure lines to a few simple typical forms; in some cases the endeavor is made to find similar maps in the belief that the various forms of pressure and temperature distribution repeat themselves in the course of time.

The method of finding similar maps may be dismissed with the remark that *no two weather maps are identical in all respects*. Occasionally two maps may be found with a number of points in common, but close examination will always reveal points of dissimilarity, especially in the antecedent conditions. The classification of weather maps according to geographic position and manner of origin is to be commended. In no other way will the student get a better appreciation of the almost numberless variations that are possible on any single type that he may select. One of the chief difficulties in the way of a working classification is the great number of sub-types into which any general type naturally falls. The usefulness of any system of classification diminishes directly as the number of sub-types increases, since in actual practice the forecaster is utterly unable to recall or recognize off hand the particular map or set of maps that the one in hand resembles. It is advisable, therefore, to limit the classification to a small number of general types and to forecast only the average conditions which are probable under the prevalence of any given type. In the United States the following working classification is suggested:

Working Classification of Storms in the United States According to Origin and Subsequent Movement.—(1) Northern boundary lows, first appearing, (a) in the North Pacific Coast States; (b) in Assiniboia.

There is a marked tendency in this group of storms to loop more and more to the southward as the cold season progresses and to pass out of the country by way of the lower lake region and St. Lawrence Valley. A very large proportion of the storms in the United States belong to this group.

(2) Middle Pacific Coast Lows; a relatively small group with a general southeastward movement across the Plateau and

Rocky Mountain region; thence northeastward to the St. Lawrence Valley.

(3) Arizona lows; most numerous in spring and fall months. These may be sub-divided into two groups, (a) those which move east-northeast to the lake region, and (b), those which take a due easterly course to the West Gulf Coast, thence northeastward to the St. Lawrence Valley via the Ohio Valley, or due eastward along the Gulf Coast passing off to sea over Florida.

(4) Eastern Rocky Mountain slope lows: a rather large group prominent in the colder months. These may be sub-divided according to the latitude. A considerable proportion of the storms comprising this group have their origin west of the Rocky Mountains, but first assume definite form over the eastern slope of the mountains.

This classification takes no account of storms originating in the Mississippi Valley, over the Gulf of Mexico, or south of Florida. It will be found, however, that fully 90 per cent. of the storms that appear in one portion or another of the United States have their origin west of the Mississippi River.

Inasmuch as it is not possible within the time at my disposal to even briefly outline the characteristics of storms which appear in the United States under the classification above given, a brief description will be given of a number of storms originating in or near the State of Kansas during the month of March in the years 1893-1902. The direction pursued by eleven of the storms, as also the rate of movement, is illustrated in the diagram below.

The various lines represent the total travel of each storm in thirty-six hours, the distance travelled in twelve hours being indicated in each case by an x in the line of total movement. From this it will be seen that, in general, the movement is east-northeast, and that the rate of motion is fairly uniform. Some of the most rapidly moving storms reached the Atlantic Coast and St. Lawrence Valley in thirty-six hours. Numbers 8, 9, 10, and 11 should be classed as erratics, that is to say either the direction pursued or the rate of motion was abnormal. Number 8 moved southeastward to Iowa, thence westward to Southeastern Nebraska, thence southward to Indian Territory. This abnormal movement illustrates an important phase of atmospheric changes in the spring months. At this time of year the great

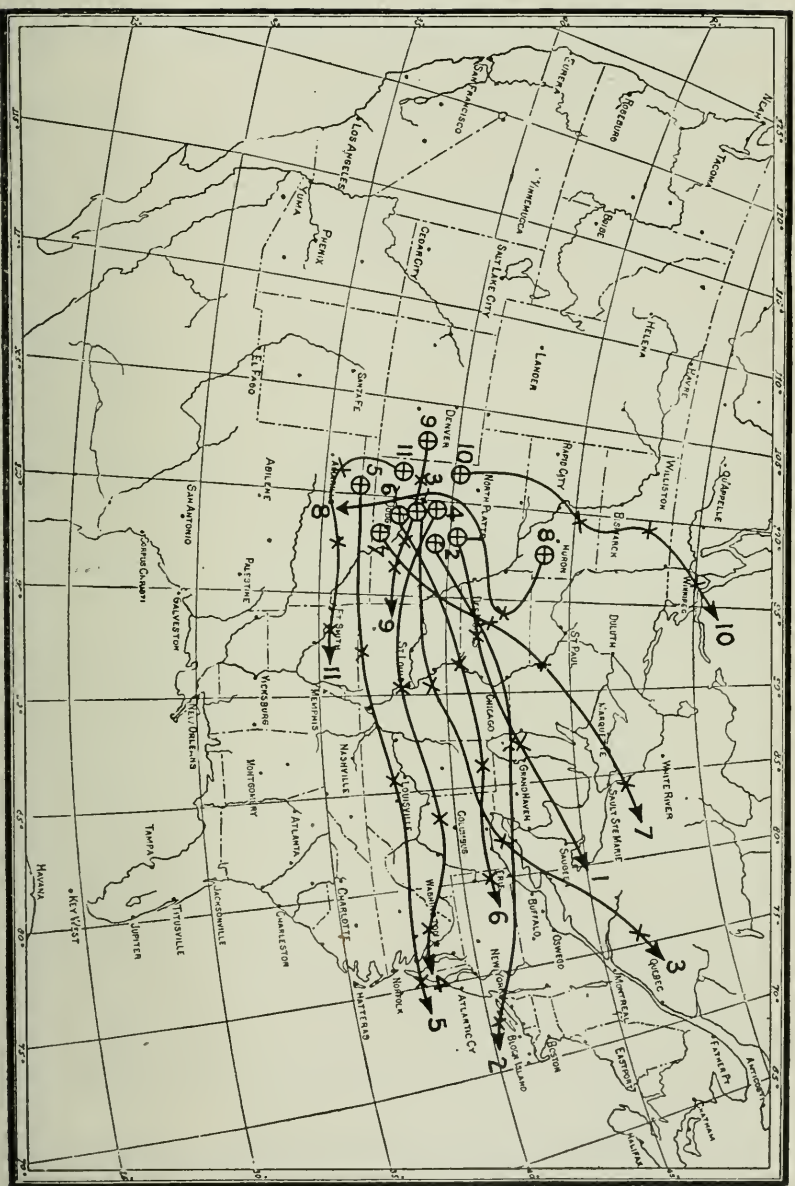


Fig. 5. Illustrating the variation in direction and rate of movement of storms having the same point of origin.

interior of the continent in the region of Hudson Bay is still ice-bound. Frequent incursions of cold air sweep thence southeastward into the St Lawrence Valley and New England, causing a marked fall in temperature over those regions. The increase in atmospheric pressure over the northern lake region that attends these incursions of cold air is strong enough to hold in check any depression that may appear west of the Mississippi River. If the depression is in the form of a long oval with its major axis east and west, the rise in pressure that spreads south and east from the Canadian border will fill up the eastern end of the depression and thus the central region of low pressure will *appear to have moved to the westward*. In this way the paths of areas of low pressure are occasionally given a westward movement on the maps of the Weather Bureau. There is still another way in which the center of an area of low pressure may appear to have moved to the westward, viz., by a fall in pressure advancing from a westerly quarter into an area of low pressure that may be stationary or slowly filling up. In this connection it should be stated that occasionally waves of falling pressure advance from west to east which are not sufficient in themselves to alter the contour of the isobars. These waves of falling pressure, or "surges," as they have been called by Abercromby, play an important part in the disintegration of the highs, and in some cases in altering the form of the lows. As just explained, a barometric surge may cause a secondary low to form to the westward of the original depression. The lows themselves, however, never move to the westward over the northern portion of the United States. In the Gulf and South Atlantic States in the hurricane season storms of this character may advance to the westward before recurving to the northeast.

The second erratic, viz., No. 9, occupied thirty-six hours in moving from Eastern Colorado to Eastern Kansas, whereas its normal movement in that time would have taken it to the lower Lake region. The slow movement in this, as in the preceding case, was due to a steady rise in pressure over the upper Lake region and in the direction of Hudson Bay.

The only storm of the group to move directly northward was No. 10. The movement of storms northward along the eastern slope of the Rocky Mountains is more pronounced in April than in March. This movement is caused, in part, by an increase in

pressure north of the Lake Superior region, supplemented by a rise in pressure over the middle California coast that advances eastward across the southern Plateau, thus forcing the depression that overlies the eastern slope of the Rocky Mountains to take a northerly course. As soon, however, as the pressure over the Lake region gives way, the storm will move eastward and down the St. Lawrence Valley.

From these concrete illustrations we may remark that failures in forecasting are due to several causes, chief of which are:

(1) Any sudden change in the rate of motion of either highs or lows.

(2) The movement of a high or low in an unexpected path or the sudden development of a low in a region where fair weather was expected.

(3) Errors in judgment of the forecaster.

(4) An important group of errors arises from the fact that even though the path of the storm be accurately forecast it is impossible to delimit with absolute precision the region over which precipitation will occur in its front, or continue in its rear.

Not very much is known of the exact processes which are concerned in the condensation of water vapor in the free air. While the evidence of the weather map points largely to the cooling due to direct contact of air masses of different temperature as the most efficient cause of precipitation, there are times when even this cause fails to produce an appreciable amount. Again rain may fall when the isobars and the general weather conditions give little, if any, indication of falling weather. Occasionally, too, a vigorous area of low pressure will pass along the northern boundary without causing any precipitation to speak of; in other cases precipitation of rain or snow will not begin until the Ohio Valley is reached, and then, without the usual preliminary clouding up to the westward. Judging from the evidence of the clouds condensation sometimes begins almost simultaneously over very considerable areas and then proceeds so rapidly that rain falls within a few hours; again the area of cloud may precede the fall of rain as much as twenty-four to thirty-six hours. The time which elapses between the clouding up of the sky and the fall of rain varies according to the form of the depression, but this subject has not been fully worked out.

Each forecaster must learn for himself the manner in which precipitation is distributed around areas of low pressure and on the front of highs in various parts of the country, and for the different seasons. The relation of the temperature to precipitation must also be carefully observed. In the winter months high temperatures are inimical to precipitation and accordingly the forecaster must withhold his prediction of rain until the center of the storm has passed and the cold westerly winds have set in. The distance that rain falls in advance of the storm center ranges from 1000 miles in extreme cases to less than 100 miles. In general the forecaster errs in placing the rain front too far in advance rather than not far enough. When the center of the low overlies the Middle Gulf Coast in the cold season and an area of high pressure lies to the northeastward with its crest over Nova Scotia, rain or snow is likely to extend to the southern New England Coast in twenty-four hours, other conditions being favorable. But should the area of high pressure be directly north of the center of the low, say over the Lake region instead of Nova Scotia, the northern limit of precipitation will not advance beyond southern Tennessee and North Carolina. In the last-named case the motion of both high and low is eastward and parallel and the line of no precipitation is sharply drawn in an east and west direction.

The chart below has been constructed to show for two different types of maps the area over which a forecast of precipitation would be successful in 80 to 100 per cent. of the cases, and where successful in only 50 to 80 per cent. of the cases. This chart fully confirms the previous statement that in the nature of the case it is not possible with our present knowledge of the subject to delimit the exact boundary of the region of precipitation; therefore there must always be a margin of greater or less extent surrounding the center of the rain area where the forecasts fail.

Notwithstanding the natural difficulties of the problem there has been a small gain in the accuracy of the forecasts in recent years, the period covered by the forecasts has been extended from eight to forty-eight hours, and instead of forecasts expressed in very general terms for large areas, definitive forecasts are now made for all of the larger towns and cities and for each of the states and territories regardless of its area. The most important gain in recent years, however, is in the adaptation of the

forecasts to the needs of special industries in various parts of the country, the perfection of the system of flood warnings and the general improvement in warnings of severe storms and cold waves.

SCANDINAVIAN WATER POWER.

The opinion has frequently been expressed that Scandinavia, with its huge waterfalls, will before very long be one of the most suitable places for large chemical works; indeed, it is claimed that with the future developments of electrochemical technology the greater part of the world's supply of soda, chlorates, nitrates, calcium chloride, and iron will be produced in the northern peninsula. Hence it is easy to understand the action of the Swedish and Norwegian Governments in protecting the falls against foreign capitalists. Sweden has passed a law that the use of the falls is reserved to the State, while a bill is before the Norwegian Storting in which it is prescribed that at least one-half of the capital laid out on the falls shall be Norwegian money, and the direction of the work be in the hands of Norwegians who are living in the land.—*London Nature*.

STANDARD TEST FOR TRANSFORMERS AND TRANSFORMER IRON.

In a paper read before the Birmingham Section of the Institution of Electrical Engineers on April 25, Dr. D. K. Morris and Mr. G. A. Lister proposed a standard test for transformers and transformer iron. The method involves but one set of connections, three instruments, and the normal supply, and necessitates the use of two similar transformers. It is a modification of that first described in 1892 by Ayrton and Sumpner, and is an application of the Kapp-Hopkinson or differential method of testing direct-current machines. The behaviour of a transformer when loaded at various power factors is, they find, best considered by means of a regulation diagram which they have constructed. The short-circuit test can equally well be carried out with a transformer core excited. The three-point wattmeter method is probably the most accurate means of measuring power factor and current when carrying out single-phase tests on transformers or motors from a three-phase supply. By bringing the supply to the middle point in the testing transformer when carrying out the differential test, symmetrical conditions are obtained, thus permitting of a normal determination of the various losses. By varying the voltage only and taking wattmeter readings the core loss of a transformer may be separated into hysteresis and eddy-current loss by the method of the total index. Wattmeter readings in combination with the three-point method serve as the best means of measuring the temperature rise in heating tests. The method of constant induced voltage affords a ready means of finding the true hysteresis loss, and is probably the best way of testing iron samples.—*London Nature*.

Development of the Theory for the Kinetic Energy of Gases.

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Heat is the reaction of work and is expressed by the difference in temperature involved ($T - T_0$) multiplied by heat capacity. The absolute temperature is the measure of the intensity of heat, while the heat capacity is the resistance of temperature.

Force is the motive power for work, and when n indicates the range of pressure in atmospheres per square meter $n^{\frac{k-1}{k}}$ is directly proportional to the absolute temperature, which, therefore, is the natural expression of force.

The attractive force begins at one atmosphere, and is, therefore ($n^{\frac{k-1}{k}} - 1$) when the centrifugal force works below the atmosphere and is expressed $n^{\frac{2(k-1)}{k}}$, because two equal force are always at hand.

If n represents the range of pressure in atmospheres, determined by the product of the initial pressure and final volume, or the pressure at the beginning and the volume at the end of expansion, our principal energy formula is $n^{\frac{2(k-1)}{k}} (n^{\frac{k-1}{k}} - 1) \frac{C_v}{2} 546$, in which $n^{\frac{2(k-1)}{k}}$ is the two centrifugal forces; ($n^{\frac{k-1}{k}} - 1$), the attractive force; $\frac{C_v}{2}$, the ratio of the molecular heat to the heat of expansion, and 546 the unit of energy in calories, derived from $\frac{22.3 \times 10630}{426}$ or the unit of pressure per square meter, multiplied by the number of cubic meters per molecule and divided by 426, the equivalent of heat in kilogrammeters.

A greater range of pressure than corresponds to the product of the initial pressure and final volume is always at hand, but the development of any range of pressure without increasing the volume does not create any work. It is necessary that both pressure and volume develop simultaneously in order to constitute a force.

In order to deduce this formula it must first be considered that a gas always consists of molecules and a gaseous matter around each molecule. If this gaseous medium for a moment is exposed to $n-1$ atmospheres' absolute pressure, a part is taken up by the gaseous medium, and the rest by the molecule.

Let us assume that in a given mass of any particular gas, such as oxygen, nitrogen, or steam, all the molecules are in rotation in a particular direction around parallel axes, and that the gas can expand only in a particular direction.

The effect of pressure on the molecule depends on the angle between the axis of rotation and the line of expansion, which we indicate by d . The greater the angle d , the less is the effect of pressure on the molecule, therefore this effect is marked $\cos d$. The effect of the pressure on the gaseous medium is consequently $1 - \cos d$.

The pressure on the ether multiplied by the effect belonging to the ether, must be equal to the resistance of the molecule multiplied by the effect of pressure on the same, in order that the action and reaction shall be alike. If the resistance is marked R , the following equation expresses this:

$$(n-1) (1-\cos d) = R \cos d; \quad n-1 = R \frac{\cos d}{1-\cos d}$$

The effect of the pressure is heat, and the ratio of the heat taken up by the molecule to that taken up by the ether stands in proportion as the molecular heat is to the heat of expansion, or $\frac{c_v}{2}$, which is equivalent to $\frac{\cos d}{1-\cos d}$.

If instead of the resistance R , we substitute the product of the forces belonging to the molecule, we will have the following formula, as all the free forces act simultaneously:

$$n-1 = n \frac{\frac{1}{2}(k-1)}{k} \left(n \frac{k-1}{k} - 1 \right) \frac{c_v}{2}.$$

Multiplying both sides of this equation by the unity of energy,

we arrive at the formula $(n-1) 546 = n^{\frac{2(k-1)}{k}} (n^{\frac{k-1}{k}} - 1) \times \frac{c_v}{2} \times 546$.

The formula for the kinetic energy of gases can be deduced from the above formula by observing that $n^{\frac{2(k-1)}{k}} = 4 (n^{\frac{k-1}{k}} - 1)$, which can be seen by substituting in the principal formula different values of n up to 27. Wherefore it can be written $4 (n^{\frac{k-1}{2k}} - 1)^2 \times \frac{c_v}{2} \times 546$.

We divide $\frac{k-1}{k}$ by 2, however, because when the kinetic energy develops, no change in volume of the molecule proper takes place, as the molecule expands adiabatically as much as it contracts by cooling in consequence of falling temperatures. Thus the formula will be:

$$4 (n^{\frac{k-1}{2k}} - 1)^2 \times \frac{c_v}{2} \times 546.$$

The temperature necessary for the reaction must first be determined from which the kinetic energy can be calculated from absorbed heat and compared with the formula.

As can be readily understood, the higher the range of pressure is, the higher must be the initial temperature, in order that the kinetic energy may be expressed by the reduction in temperature.

It must also be remembered that heat alone cannot increase the kinetic energy, if the range of pressure is not increased at the same time, which can be understood from the fact that the heat is not the acting but the reacting force, just as in all chemical operations.

When the temperature of a gas is raised by adiabatic compression, the temperature of the kinetic energy is lowered, but not by the same amount for equal pressures, because the heat capacity must be counted as c_p at constant pressure by expansion, instead of c_v at constant volume by the compression.

In case c_v is the heat capacity during the expansion, the action of the gas would be perfectly reversible from one direction to the opposite; but it will be found by closer examination that

this is only a mathematical fiction. Not one such phenomenon as perfect reversibility exists, either of a chemical or a physical nature.

When the attractive force is used for compression, the centrifugal force acts during the expansion. It would be a peculiar coincidence if the square of a force in every instance would be equal to a linear force.

Besides, the heat capacity for air and steam is vacuum, which are both derived from c_p , shows conclusively that c_p is the true heat capacity during the expansion.

This change in heat capacity makes the fall of temperature for equal reduction of pressure caused by expansion of an ideal gas at $\frac{t}{1.41}$ of the temperature created by compression, depending, however, on the relation of the index of the kinetic energy in comparison with the index of the adiabatic compression, because the temperature is influenced not only by the heat capacity but also the heat quantity involved.

For instance, to compress a molecule of gas at 80° absolute temperature until the temperature is raised to 273° , it will take 68 atmospheres' pressure, whence the index of the adiabatic compression is $(3.4 - 1) = 2.4$.

On account of the heat capacity of expansion being different from that of compression, the adiabatic index must be altered to $1.41 \times 2.4 = 3.384$. On account of which it will take 91 atmospheres range of pressure from the beginning to lower that temperature to 80° , which can be seen from the following equation:

$$\text{tion: } 4(91^{\frac{0.22}{2}} - 1)^2 = 3.384.$$

While by the adiabatic compression 256 atmospheres are needed to raise the temperature from 80° to 400° at an index of $(5 - 1) = 4$, the range of pressure needed for the kinetic energy to lower the temperature to 80° from 400° , will only be 220 atmospheres, because the index for the kinetic energy being $1.41 \times 4 = 5.64$, would amount to that figure, namely,

$$4(220^{\frac{0.22}{2}} - 1)^2 = 5.64.$$

In the same way it is necessary to have respectively, 525, 740 and 1480 atmospheres' pressure to raise the temperature from 80° respectively to 493° , 546° and 667° , when only 364, 458 and

740 atmospheres, respectively, range of pressure are necessary for the kinetic energy to lower the temperatures from respectively 493° , 546° and 667° to 80° .

Herewith it will be shown that the kinetic energy stands in direct ratio to the reduced temperature from the initial temperature to 80° , the same as we have stated above. Wherefore we consider these temperatures necessary in order that the energies should correspond with our formula.

The reduced temperatures 193° , 320° , 413° , 466° and 586° multiplied by 23 give the following products: 4435, 7360, 9499 and 10,718, and 13,474 cal., when the kinetic energies for 91, 220, 364 and 458 range of pressure are respectively 4436, 7388, 9530, 10,750 and 13,570 cal.

For this reason we must consider 23 as the proper heat capacity of the molecule of air when expanding and rendering work, and 6.8 the heat capacity when the air expands against atmospheric pressure. This can be explained from the fact that volume and heat capacity are most intimately related to each other, so that the heat capacity for all bodies is altered by any change of volume. Heat is the reactive force on which the heat capacity and temperature depend, and the reactive force is proportional to the square of the volume, but in such a way that the heat capacity, under free expansion, is half the square of the heat capacity when expanding against atmospheric pressure. In other words, the square of the heat capacity is divided equally among the atoms of the molecule.

The development of the volume depends on the range of pressure, or the product of pressure and volume, which determines the kinetic energy, and if we give the gases enough temperature to be reduced, the kinetic energy will be equal to 23 multiplied by the reduced temperatures, or $Q = (T_1 - T_2) \times 23$ and our equation,

$$4 \left(n^{\frac{k-1}{k}} - 1 \right)^2 \times c_v \times 273 = (T_1 - T_2) \times 23.$$

in which T_1 is the absolute temperature at the beginning and T_2 at the end of expansion.

RELATION BETWEEN PRESSURE AND VOLUME.

The volume, as defined in thermodynamics, cannot show how the force acts, or how much energy is evolved, and in order to

do that we go to the vacuum or the developed volume, which together with the original pressure, will give us a basis for it.

Instead of the final volume, we use the term vacuum = v .

Instead of initial pressure = p , we use only the term pressure, and will define the pressure if otherwise intended.

As we consider vacuum to be an expression for volume and not for pressure, we will define it: The unit of vacuum for air consists of 0.5 volumes of absolute vacuum and 0.5 volume of air, and every additional unit has two volumes of absolute vacuum, each equal to the volume of the air, so that any magnitude of vacuum always contains 0.5 volume of air.

To determine the relation between vacuum and pressure we assume that $p^{0.71} = v$ for absolute vacuum, and as we have the range of pressure, or $p v$ given, we can determine the vacuums and pressures, the product of which must be equal to the range of pressure.

p =pressure	14	23.5	31.5	36	47.7
v =vacuum	6.5	9.41	11.6	12.8	15.5
$p v$ =range of pressure.....	91	220	365	458	470

If to the absolute vacuum is added 0.5 volume of air at its temperature in vacuum, we have the following values:

p = ...	13	22.2	30	34.7	46.7
v = ...	7	9.91	12.1	13.3	16
$p v$ = ...	91	220	363	460	740
T_1 = ...	273°	400°	393°	546°	667°

From the last figures we can find that $v^2 T = p^2 \times 80$.

$$\begin{aligned}
 7^2 \times 273 &= 13377; 13^2 \times 80 = 13520 \\
 9.91^2 \times 400 &= 39684; 22.2^2 \times 80 = 39440 \\
 12.1^2 \times 493 &= 72175; 30^2 \times 80 = 72000 \\
 13.3^2 \times 546 &= 96532; 34.7^2 \times 80 = 96320 \\
 16^2 \times 667 &= 170752; 46^2 \times 80 = 170752
 \end{aligned}$$

From the last figures it can be seen that the square of the ratio of pressure to vacuum is equal to the ratio of the initial to the final temperature.

If we assume that vacuum is equal to the ratio of the initial to the final temperature multiplied by 2, we obtain the following values of vacuum: 6.82; 10; 12.3; 13.6, and 16.6, which favorably compare with the above, 7; 9.91; 12.1; 13.6, and 16, respectively.

We consider, therefore, this part of our theory a fully established, as the reduced temperature and heat capacity have been fully demonstrated.

We will now present another method of demonstrating the same thing.

DETERMINING THE KINETIC ENERGY BY THE PRODUCT OF THE FORCES.

When vacuum is arranged to correspond to the pressure, it can be concluded that the three natural forces work at their full capacity at the same magnitude, and that the amount of work is in proportion to the product of them.

One force is $n^{0.29}$, where n is the pressure in atmospheres, and consequently the product of the three forces is $n^{0.87}$. This product must be multiplied by the unit of energy per molecule, 546 cal., deduced from one atmosphere's pressure per molecule, divided by the equivalent of heat, $\frac{22.3 \times 10360}{426}$, after deducting the amount due to vacuum.

If the vacuum is 7 the unit of energy will be $546 (1 - \frac{1}{7})$ cal. = 468 cal. per molecule.

In the same way for respectively 12.1; 13.3, and 16 vacuum, the unit will be 492; 500; 505, and 512 cal.

The forces for 13; 22.2; 30; 34.7, and 46.2 atmospheres' pressures are as follows:

$13^{0.87} = 9.31$	which multiplied by 468 makes	4367 cal.
$22.0^{0.87} = 14.8$	" " "	492 " 7282 "
$30^{0.87} = 19.2$	" " "	500 " 9610 "
$34.7^{0.87} = 21.9$	" " "	505 " 11059 "
$46^{0.87} = 28$	" " "	512 " 14336 "

From the fact that the heat capacity is constant during the expansion, it follows that $\frac{\cos. d}{1 - \cos. d}$, no matter how great d is, remains constant, and consequently the angle d must be constant. Therefore it can be concluded that the curve of expansion is a logarithmic spiral.

Our formula for the kinetic energy is confirmed, not only by the temperature and heat capacity, but also by the product of the three forces.

Comparing the results of the three methods for determining the kinetic energy, we have the following results:

Range of Pressure.	Product of Forces.	Reactive Forces.	Principal Formula.
91	4367 Cal.	4435 Cal.	4436 Cal.
220	7282 "	7360 "	7288 "
363	9610 "	9499 "	9520 "
460	11059 "	10915 "	10750 "
740	14336 "	13478 "	13570 "

This table shows that our formula for the kinetic energy is correct for air when a vacuum corresponding to the pressure is available, and now we will see that the formula holds good under other conditions.

ENERGY DERIVED WHEN THE PRESSURE WORKS AGAINST ATMOSPHERE.

In the range of pressures the vacuum can be replaced by the product of temperature and pressure, making the final temperature 3.4 times greater, in which case we have only one volume per molecule to deal with, and then the heat capacity will be 6.8 cal. per molecule.

If, for instance, instead of 7 vacuum and 13 pressure, we make the pressure 91, it will give the former energy 4433 cal. by an initial temperature of 273° instead of 80° . In this case the reduced temperature must be $\frac{3.384}{1.41} = 2.4$. or $2.4 \times 273 = 655^{\circ}$; whereas the energy is $655 \times 6.8 = 4454$ cal.

In the same way the following examples are calculated:

Atms. Pres.	Index for Kinetic Energy.	The Same Index	Reduced Tem.
6	0.349	1.41	67°
9	0.584	0.248	112°
12	0.74	0.42	143°
16	0.96	0.527	185°
	0.68		
Pressure.	Energy from Reduced Temperature.	Energy from Formula.	
6	$67 \times 6.8 = 456$ Cal.;	$0.346 \times 1310 = 457$ Cal.	
9	$112 \times 6.8 = 761$ "	$0.584 \times " = 765$ "	
12	$143 \times 6.8 = 970$ "	$0.74 \times " = 970$ "	
16	$185 \times 6.8 = 1258$ "	$0.96 \times " = 1257$ "	

The vacuum can be diminished to any amount and replaced by pressure if the temperature is raised to corresponding

height, which, however, on account of the high temperature, can only be used for a small range of pressure.

According to the law of conservation of energy, and as a consequence of an adiabatic compression or expansion against the atmosphere, it follows that the product of pressure and volume divided by an absolute temperature remains constant in all

stages of proceedings, or that $\frac{p_1 v_1}{T_1} = \frac{p_2 v_2}{T_2}$.

As c_p is the true heat capacity during the expansion $p v^k$, will not be constant during the expansion as it is at the compression, in particular for air equal to 1.

This conclusion can be substantiated by the following table:

p	p ₂	v ₁	v ₂	T ₁	T ₂
6	1.	0.28	1.42	436°	389°
7	1.	0.21	1.48	516°	404°
12	1.	0.1715	1.537	562°	419°
16	1.	0.14	1.86	611°	426°
91	1.	0.04	1.286	1010°	355°

From this follows that the formula for the second law cannot be used, as the law postulates that $p v^k$ must be constant in both cases.

Adherents to the second law claim, however, that c_v is the true heat capacity when the air expands against varying pressure. This illusion is taken away when the facts are considered that the kinetic energy and the energy of the adiabatic compression never have been found perfectly alike, which would be the consequence in this case.

(To be concluded.)

Franklin Institute.

(Proceedings of the stated meeting held Wednesday, September 19, 1906.)

HALL OF THE INSTITUTE,
Philadelphia, Sept. 19, 1906.

PRESIDENT JOHN BIRKINBINE, in the chair.

Present, twelve members.

Additions to membership since last report, fourteen.

The Actuary reported the death of Mr. Robt. C. H. Brock, a member

of the Board of Managers. The President, in referring to the circumstance, expressed the extreme regrets of the Board at the loss of one of its most active and valued members, and stated that the Board had already taken steps to name a committee to prepare a suitable memorial of its deceased member for publication in the *Journal*. The choice of a successor to Mr. Brock was, on motion, postponed until the annual election.

The President then introduced Prof. Lewis M. Haupt, who presented a communication on "The Relations of the Government to Our Waterways." The speaker's remarks were freely illustrated with the aid of lantern views.

At the close of Prof. Haupt's remarks, he offered the following preamble and resolutions, which were unanimously adopted:

WHEREAS, It is the present established policy of the General Government to provide ample facilities for the water-borne commerce of the United States and to emancipate inter-state commerce from the obstructions imposed by tolls or restricted canals under private or corporate control,

WHEREAS, This policy has been successfully inaugurated in all parts of the country with the exception of the early canals skirting the most populous and important cities of the Atlantic seaboard, and

WHEREAS, The best interests of the country demand the early construction of capacious canals connecting the interior waters of the bays and sounds of this coast, for commercial purposes as well as for national defense, and

WHEREAS, The most important and least expensive of these links is the one connecting the waters of the Chesapeake and Delaware Bays by a canal which is less than fourteen miles in length, and which has a trunk of only nine feet in depth and sixty-six feet minimum width, in which the Government is a joint owner, and concerning which its officials and commissions have invariably reported that it is vital for the protection of the coast, as has been demonstrated in our several wars, and

WHEREAS Congress has again authorized the appointment of a Commission to ascertain the expense of securing control of the works and franchises of the Chesapeake and Delaware Canal with a view to the acquisition of the aforesaid canal as a free and open waterway, which Commission is to report at the coming session of Congress.

Be it therefore *Resolved*, That the Franklin Institute of Pennsylvania reaffirms its position as to the urgent necessity of enlarging our coastwise waterways, and especially the Chesapeake and Delaware Canal for commercial and strategic purposes at the earliest practicable date.

Resolved, That a Committee be appointed to present this resolution to the Commission at the public hearing to be held in this city on the 27th inst.

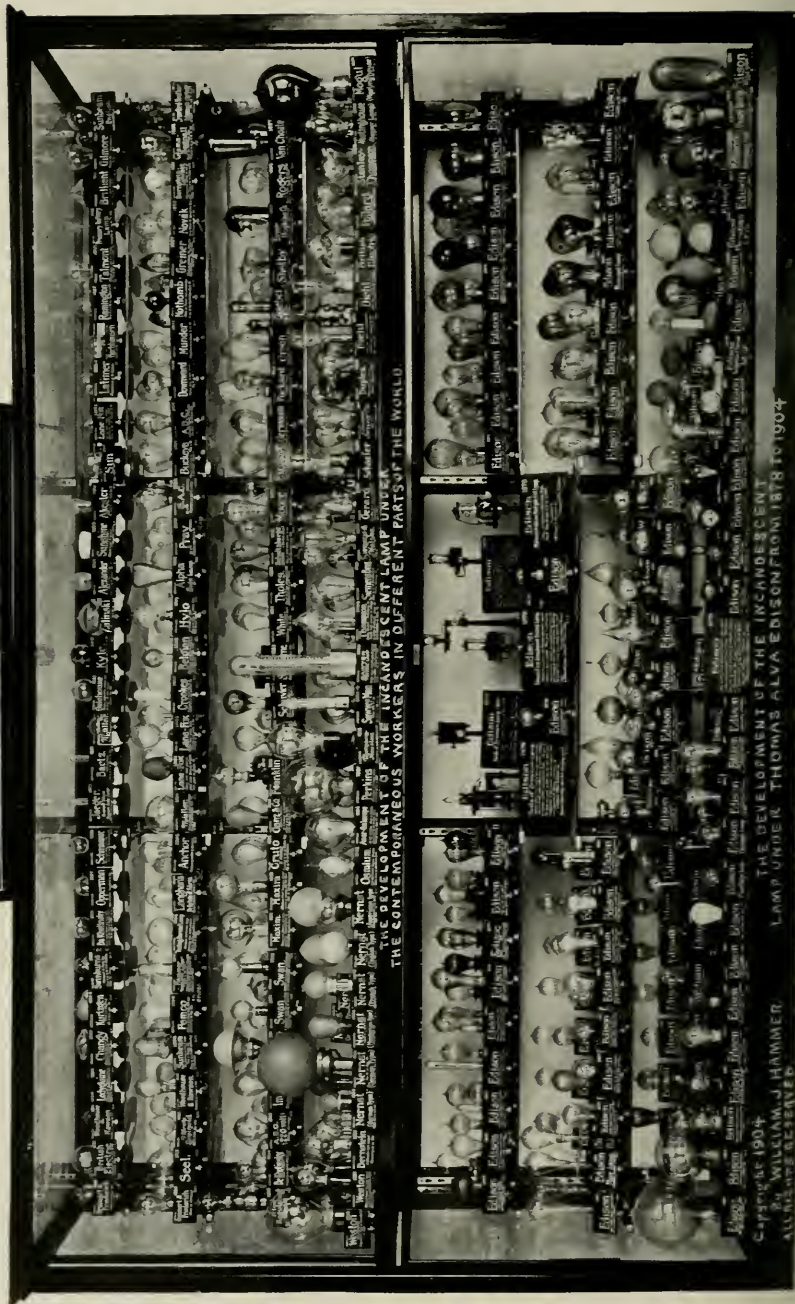
The President, in accordance with the foregoing action, named Prof. Lewis M. Haupt, Dr. W. J. Williams and Dr. E. Goldsmith as members of the special committee to transmit the preamble and resolution to the Commission on the Chesapeake and Delaware Canal, which is to meet at the Philadelphia Bourse on Thursday, September 27th. Adjourned.

W. J. WILLIAMS, *Sec'y pro tem*.



THE HISTORY OF AN ART

Historical Collection of Incandescent Electric Lamps.
Property of William J. Hammer, Consulting Electrical Engineer.
NEW YORK.



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THE FRANKLIN INSTITUTE.

The William J. Hammer Collection of Incandescent Electric Lamps.

[Being the Report of the Committee on Science and the Arts on the Historical Collection of Incandescent Electric Lamps made and Exhibited at the St. Louis Exposition of 1904, by Mr. William J. Hammer. Sub-Committee: C. J. Reed, Chairman; Carl Hering, Thomas Spencer.]

[No. 2385.]

The Franklin Institute, acting through its Committee on Science and the Arts, investigating the merits of the collection of more than 1000 incandescent electric lamps, made by Mr. William J. Hammer, of New York, reports as follows:—

This collection of lamps, made during a period covering more than a quarter of a century, may truly be said to represent the "History of the Art." This history embodied in this collection is not a history that could have been recorded in words, that could be duplicated by any process or reproduced if destroyed.

It is the result of the most vigilant and systematic efforts on the part of the collector during the past twenty-five years and over, not only in the United States, but in many countries of Europe during his various sojourns abroad, which covered altogether about six years. The collection was started in 1879, when, at the beginning of Mr. Edison's work, Mr. Hammer had charge, in Mr. Edison's laboratory at Menlo Park, N. J., of certain tests and records relative to the life, efficiency and general characteristics of the Edison lamps. Mr. Hammer was afterwards appointed electrician of the first Edison lamp factory at Menlo Park and here he obtained much of the material forming the earlier part of the collection.

At a great personal outlay of time, labor, thought, and money, he has secured material showing practically every step in its development, from Edison's early platinum thermostatic-regulator lamp, platinum-iridium spiral lamps, multiple foil platinum lamps, oxide-of-zirconium lamps of 1878, up to the most modern type of lamps. The collection embraces, not only the entire art under Edison, dating from his first commercial lamp, the famous "paper horse-shoe" lamp of 1879, his plumbago, graphite, bamboo, and other vegetable filament lamps, but also the work of Edison's contemporaries here and abroad from this early period down to the present time, including the following:—

Swan, also Edison-Swan, Ediswan, Swan United and Brush-Swan types, Lane-Fox, Maxim, Weston, DeChangy, Sawyer, Lodyguine molybdenum, Cruto, Gatehouse, Kurtzgen, Swinburne, Crookes, Bernstein, Müller, Boehm, Gerard, Latimer, Rogers, Opperman, Diehl, Thompson, Stanley-Thompson, Thomson-Houston, Remington, British Electric, Akester, Alexander, Richter, Schuyler, Duplex Co., Siemens & Halske, Siemens Bros., Greinert & Friederich, Vitrite-Luminoid, Sawyer, Sawyer-Man, Nothomb, Hochhausen, Hammer, Sun, Franklin, Schmauser, Greiner, Schaefer, Jenny, White, Excelsior, Belgian, and includes also the more modern development under Ganz & Co., United Electric, Von Choate, Guest, Phoenix, Gilmore, Sun-Star, Solar, Monarch, Colonial, Economy, Brilliant, Tipless, Sterling, Comet, Capital, Goebel, Von Kameron, Dubligo, Elblight, Zenith, American, A. E. G., New Universal, "Watt," Hardy, Trilight, Fostoria, Malden, Esco, Meriden, T. A. Edison, Jr., Tipless, "Guage," Premier, Miller, Buckeye, Femco, S. A. C., Sunbeam, Packard, Perkins, Boston, Westinghouse, Novak, Columbia, Seel, Pray, A. B. C., DeKhotinsky, Zugh, Peerless, Orient, Banner, Downward, Hylo, Economical, An-

chor, Munder, Brian-Marsh, Empire, Fabius-Henrion, Compagnie Centrale d'Electricite, Compagnie General des Lampes, Larnaude, Zurcher, Gelnhausen, Pintsch, Bayeische, Goosens-Pope, Phillips, Kremenetzsky, Schonlah & Scharfs, Clerici, Vereingite E. A. G., Strum, Heany tungsten, Talmont, Adams, Bagnal, Hammer "Radium", Pollard, Imperial, Thowles, Shelby, Kyle, Zaslinsky, Kentucky, Star, O'Brien, Sunshine, Germania, Nernst, Moore, Osmium, Aueros, Osmi, Langhans, Crawford-Voelker, Tantalum, New Edison Graphitic Lamp, Kuzel, etc.

In nearly all cases the lamps constituting this collection are the very first ones or among the first made by the respective inventors. Some are the only lamps of their type which have been made and they are all samples constructed early in the development of the period to which they belong. The collection comprises over 1000 lamps, each marking an important step, experimental or otherwise, in the development of the art. Mr. Hammer received the "Grand Prize" for his collection at the St. Louis Exposition of 1904.

The Committee feels that it can express its opinion as to the great historical value of this monumental collection in no better way than to quote from the letters and statements of a few of the ablest men of the scientific, engineering and commercial world, of whom over 200 have expressed themselves on the world, of whom over 200 have expressed themselves on the subject:

Prof. Elihu Thomson says of the collection: "It is perfectly unique, covers the whole period of development of the lamp, and it must be admitted by any one at all familiar with the circumstances that no similar collection could ever again be gotten together; in other words, your collection is impossible of duplication, or even approximate duplication. This statement cannot be made too strong."

Lieut. W. V. N. Powelson, Chairman of the Departmental Jury having supervision over the work of all the Electrical Group Juries, after the various members of the Jury had spoken in high appreciation of the collection, said: "In my opinion if the St. Louis Exposition were to give but a single Grand Prize, it should be awarded to William J. Hammer."

The following are extracts from some of the 200 letters which Mr. Hammer received, many of which are from leading authorities here and abroad. The originals were submitted to the Committee for examination. They are given here in the

order in which they happen to be and not necessarily in the order of their importance:

"I esteem it as a complete and unique showing of the progress of the Art from its first beginning to the present time and very valuable in that it cannot be duplicated. As such it would please me greatly if it could be secured by some institution where it would be safe from destruction and where it could be studied by every one so desiring."

CHARLES BATCHELOR.

"I would like to see your collection remain in America as a priceless history of an art . . . You have the only collection of the kind in the world, as you have followed up your early collecting not only in this country, but in Europe."

F. R. UPTON.

"This collection is worthy of being permanently preserved in a most careful and safe manner so that it may be accessible to electrical specialists and to the public generally."

PROF. FRANCIS B. CROCKER,
Columbia University.

"I regard your collection of historical incandescent lamps as unique in the Arts and as of the very greatest interest to all students of the history of this art. I consider that you have done great service to all such students by the pains you have taken to save the collection and exhibit it."

PROF. A. E. KENNELLY,
Harvard University.

"I consider this collection as of extreme value. Indeed it is unreplaceable and becoming of increased importance with every year of advance of electrical engineering. It is a history of the Art which cannot be reproduced any more."

DR. CHAS. P. STEINMETZ.

"There can be no dispute as to the extreme value of the collection; for it is, I believe, the only collection which shows the entire development of an art from very unpromising beginnings to a complete and world-wide success."

PROF. C. F. BRACKETT,
Princeton University.

"I feel confident in saying that it is the most complete and instructive collection illustrating the development in a great industry that I have ever seen."

PROF. C. F. BURGESS,
University of Wisconsin.

"Such historical collections of apparatus as you have made are

of great interest to everybody, and are of increasing value as they are more nearly exhaustive as is the historical exhibit of incandescent lamps shown at St. Louis. The world has lost much valuable historic material in other arts for the lack of a like-minded man as yourself."

PROF. A. E. DOLBEAR,
Tufts College, Mass.

"Certainly few men have had the tenacity of purpose and persistent mastery of detail which has been necessary to the rounding out and development of this collection. It is a splendid example of what can be accomplished if in the present we map out for the future a plan of development and conscientiously carry it out. It is not often that the fulfillment of this principle is so forcibly presented in concrete form for our study."

W. E. GOLDSBOROUGH,
Chief Dept. Electricity, St. Louis Exposition, 1904.

"It is of course an exhibit that cannot be duplicated and one which reflects great credit on your patience and skill in getting it together. As a complete history of the development of an art of world-wide importance it undoubtedly stands alone, and as such is of great interest and value to both laymen and engineers."

FRANK J. SPRAGUE, Con. Elec. Eng.

"I believe it can be said without fear of contradiction that no other art has been so completely recorded as to its rise and progress by original physical exhibits. As it stands to-day it is a liberal education to study it. . . . I think a man who thus anticipates during the growth of a new art the needs of future history and of education, by patiently and systematically following up every clue in many lands, should be recompensed also for the foresight which has led him to do what others have overlooked as unimportant or given up as too laborious."

W. J. JENKS,
Sec'y Board of Patent Control.

"I remember well how eagerly you commenced your collection in the latter part of 1879 at Menlo Park, N. J., and know also how much time and money you have since spent in completing it. Twice I have met you in Europe over-running every country in quest of lamps, and with your connections here and in the States you have succeeded in getting together a complete set of lamps that show step by step the history of incandescent lighting. The importance and value of such a complete and only-existing set of incandescent lamps as that which you possess *cannot be appraised.*"

FRANCIS JEHL,
Electrical Engineer, Budapest-Hungary.

"I regard the collection as one of great value not only because it constitutes a remarkably complete history of the development of the incandescent lamp, but also because it is an object lesson which may be expected to influence workers, in other fields, to begin early and prosecute diligently the collection of apparatus embodying records of successive steps in the advancement of other arts."

L. B. STILLWELL, Con. Elec. Eng.

"This collection is important and unique, representing as it does the entire history and progress of the art of incandescent electric lighting. Both the group and departmental electrical juries at the World's Fair took pleasure in recommending for the 'Grand Prize' your exhibit of your lamp collection and we appreciate that had it not been due to your personal effort, there would not be in existence to-day any collection adequately representing the history of the art of lighting by incandescent-electric lamps, nor could such a collection be possibly assembled."

LIEUT. W. V. N. POWELSON,
Chairman Dept. Jury, St. Louis Exposition.

"I have always regarded your collection of lamps and associated appliances as an exemplification and record incomparable in value in consequence of the evolution and wonderful growth of the art of electric illumination."

THOMAS D. LOCKWOOD, Elec. Eng.,
Am. Telephone and Telegraph Co.

"The collection of incandescent lamps which you have made illustrating the historical development of the incandescent lamp is a very valuable one and ought to be preserved in some public institution."

E. B. ROSA,
Bureau of Standards, Washington, D. C.

"I regard your collection of incandescent lamps as extremely interesting, and wish that they might find a permanent abode where they would be open to inspection by future generations."

F. P. FISH,
President Am. Telegraph and Telephone Co.

"Such a collection I should regard as being of considerable interest and much practical educational value. I trust that you will succeed in placing it where it will become a permanent exhibit."

GEORGE WESTINGHOUSE.

"In my judgment this collection of incandescent electric lamps ranks foremost among America's scientific historical collections, and as time goes on interest therein will increase and its importance to the engineering world and especially to electrical engineers of the

future will be infinitely greater and in fact invaluable. I most earnestly recommend that if possible this collection be permanently placed on exhibition where it will be safely conserved in one of our leading public institutions."

W. H. WHITESIDE,
President Allis-Chalmers Co.

"Permit me to say that your far-seeing intelligence in securing this collection, beginning at an early period that you did, merits the commendation of all interested in electrical science and electrical industry, and in this commendation I most heartily join."

CHARLES W. PRICE,
Editor Electrical Review.

"I shall rejoice to see you receive a fitting reward of your patience and industry in making this collection and in holding it together through so many years."

T. C. MARTIN,
Editor Elec. World and Engineer.

"Nothing even approaching it in uniqueness and completeness is in existence in any of the allied branches of applied science. With no missing links in your collection you have made available for the engineering world a record of Electric Lamp development of which the value is inestimable."

ALBERT SPIES,
Editor of Cassier's Magazine and Elec. Age.

"I well remember seeing these lamps at the St. Louis Exposition, and in common with all who saw it, was very greatly impressed with the perfection and completeness of the collection, which I am sure cannot be equalled by any similar one relating to a special industry in the world. I only wish that we in England could have an opportunity of access to such a valuable exhibit. As a member of the Electrical Jury at the St. Louis Exposition, I cannot do better than echo the opinion of the chairman of that jury as to the value of the collection."

DR. CHAS. V. DRYSDALE,
Northampton Institute, London, Eng.

"It goes without saying that this collection, which evidently represents the careful work of years, stands alone in technical history. To me the completeness and adequateness of the collection proves amply that it was with you entirely a labor of love. Such work is altogether too seldom seen in these days of fierce commercial competition. As such inventions may be considered among the greatest achievements of the race, it is vitally important that the historical documents illustrating the struggles and triumphs of our pioneers shall not be altogether lost."

LEE DEFORD,
Vice-President DeForest Wireless Tel. Co.

"The collection not only signifies painstaking care and patience and labor, but an unselfish devotion to electrical science, which has prevented the ruthless destruction of these lighting landmarks which represent so much life blood and brain, and which if destroyed would in future time cause the greatest of regret. While not in that section of the Electrical Jury at the Louisiana Purchase Exposition, I certainly would have voted your collection the highest prize had it been in my power."

PROF. J. C. KELSEY.

"I am certainly glad of this opportunity of once again confessing, as I have already confessed as a member of the Jury of the St. Louis Exposition, my great admiration of your historical collection, the perfection and importance of which cannot be overlooked by any student of technical history who is interested in the history and progress of the science and for this reason it is very desirable that the aforesaid collection should be placed in a position which shall easily be accessible to students."

PROF. GUIDO GRASSI, Turin, Italy.

"I consider that the person who has devoted himself to so laborious a task as was involved in creating this unique collection should be adequately recompensed by granting him the 'Grand Prize,' and for this reason I suggested in the course of our discussion on the subject of awards in the International Jury, the idea of granting to Mr. Hammer the 'Grand Prize' for his unique collection of incandescent lamps."

GASTON ROUX,

Con. Eng. and Director of Bureau of Control
of Elec. Installations, Paris, France.

In consideration of the great historical and educational value of this collection; of the years of unselfish labor and energy devoted to it; of its unreplaceable and monumental character, the Committee recommend the award of the Elliott Cresson Medal to Mr. William J. Hammer, of New York, for his "HISTORIC COLLECTION OF INCANDESCENT ELECTRIC LAMPS."

Adopted at the meeting of the Committee on Science and the Arts, held Wednesday, April 11th, 1906.

ATTEST: WM. H. WAHL, *Secretary*.

SUPPLEMENTARY NOTE BY THE EDITOR.

In connection with this report there is published a plate (*See frontispiece*), showing the appearance of this remarkable exhibit of lamps made by Mr. Hammer at the St. Louis Exposition.

Since the collection was exhibited at St. Louis, in 1904, he has supplemented it by samples of various lamps which have appeared since, particularly the Tantalum and Tungsten lamps.

It is Mr. Hammer's earnest wish that this collection shall be kept absolutely up-to-date as time passes, that it may always represent a complete "History of An Art," and to this desirable end he will always lend his enthusiastic co-operation. This has always been his wish and intention and in the years past he has been buoyed up in his laborious task by the hope that his work, if successfully carried out, would stimulate others to make similar collections forming priceless records of the inception, development and perfection of other arts, and perhaps ultimately result in an engineering museum in which engineers could deposit their models and inventions, where they would be properly safeguarded, where they would be of infinite interest to the world at large, where they would be of great service to the historian, where they would be a constant stimulation to the young engineer and to the inventor, and where they would be of enormous educational value to all engineers.

EARTHQUAKE RECORDS.

Prof. Harry Fielding Reid, of Johns Hopkins University, who is in charge of earthquake records for the United States Geological Survey, has sent out circular letters through which he expects to obtain important scientific data concerning the recent earthquake in San Francisco.

It may not be generally known that a few hundred dollars are devoted each year by the Survey to the collection of records concerning earthquakes. No very active seismological investigations have ever been made by this bureau, but a small allotment is granted Professor Reid, which enables him to correspond with observers all over the country and procure data recorded on seismographs at many different points. Reports of his investigations are published, from time to time, in the *Weather Review*, the official organ of the Weather Bureau.

It is interesting to note that Professor Reid was appointed by the State Department as delegate from the United States to the International Seismological Conference, held in Strasburg, Germany, from July 24 to 28, 1903. Delegates were present by invitation of the German Government from 19 countries, and an international association was then formed for co-operative investigation of earthquake phenomena. The constitution adopted provides for a general assembly to meet at least once in four years and a permanent commission, composed of one delegate from each nation, which will direct the work of the Association. A central bureau is

located at Strasburg in connection with the Imperial Seismological Station there, and reports are forwarded to its Director and are published from time to time.

The Association was joined by many countries, but the United States has not yet signified its intention of becoming a member. The permanent commission or executive committee of the Association was organized in Berlin last summer. Professor Reid was present at this meeting also. After his return he recommended, as he did after his return from the Strasburg conference, that the United States join the Association.

The Director of the Geological Survey has recommended in a letter to the Secretary of the Interior that the United States accept the invitation of the German Government to join the International Seismological Association, provided that Congress shall see fit to make the necessary appropriation. The total sum that Congress is called on to appropriate annually is \$1,300, which includes \$800, the fee that the United States would be required to contribute to the Association and \$500 for the expenses of the delegate.

It is not likely that a delegate from the United States will ever have anything more important or more disastrous to report than the records of the earthquake which devastated the metropolis of the Pacific coast.

THE USES OF FLUORSPAR.

The highest grade of fluorspar, "American lump, No. 1," says Mr. Edmund Otis Hovey in a report of the United States Geological Survey on the production of fluorspar in 1905, is pure white or clear pale blue in color and does not contain more than 1 per cent. of silica. Such material is used in the manufacture of opalescent glass, in the making of enamels and "agate" ware, and in the production of hydrofluoric acid and other chemical compounds of fluorine. Both lump and ground mineral is shipped for these purposes.

The second grade of fluorspar, "American lump, No. 2," includes the colored varieties and is limited to a content of not more than 4 per cent. of silica. This is sold in lump or gravel form and is used in the manufacture of open-hearth steel, because it imparts great fluidity to the slag.

The third grade of fluorspar "gravel" includes all of the mineral that carries more than 4 per cent. of silica and all that is mixed with calcite. This material is used in foundry work on account of the clean character which it gives to iron castings. Through lack of knowledge of this property the demand for fluorspar for foundry work is much less than it should be.

Other grades known to the market are "crushed," "ground fine," and "ground extra fine."

GERMANY'S production of coal in the first half of 1906 was 67,257,295 metric tons, against 56,630,591 tons in the corresponding period of 1905. The production of coke for the half year was 9,778,480 tons, as compared with 6,554,776 tons in the first half of 1905.

A New Primary Battery for Large Currents.

(Abstract of the remarks of PROF. CARL HERING at the stated meeting held October 18th, 1906.)

At the monthly meeting of the Institute, held October 18th, Mr. Carl Hering, in his capacity as Professor of Electrical Engineering of the Franklin Institute, and at the request of the Secretary to bring before the Institute new developments of importance in the electrical field, made some remarks on a new and interesting form of primary battery for relatively large outputs, known as the Decker Primary Battery, which were accompanied by exhibits of the battery and its parts. Prof. Hering spoke substantially as follows:

Primary electric batteries for any but very small currents have had a bad reputation for many years. This is very unfortunate, as the primary battery in its proper place is an extremely useful and convenient generator of electricity. The fact that one company alone is said to be making and selling 100,000 per day, is conclusive proof that the primary battery in its proper sphere is an extremely useful article. The primary battery preceded the dynamo, but the latter has, during the past thirty years, made such enormous strides that its predecessor, the primary battery, was relegated to obscurity and its development was greatly neglected. A well known authority recently said that for the past fifty years no improvement had been made in primary batteries. It certainly cannot be denied that remarkably few improvements of any value have been made during that period.

The reasons why the primary battery has had such a bad reputation seem to be that so many batteries were brought out which were fakes and mere impositions on the public; and that so many inventors and promoters have neglected and tried to obscure the important question of the cost of the materials

which were consumed in every primary battery; the users were left to find this out for themselves; and thirdly, that primary batteries for relatively large currents have generally been constructed very badly from a mechanical point of view; they were extremely awkward to handle, were irrationally proportioned, were very difficult to keep clean, and the process of filling and emptying were very sloppy and tedious.

The primary battery in principle is a far more efficient generator of electricity than the steam or gas engine driven dynamo; that is, it is a very much more perfect converter of chemical energy into electrical energy, as it is not limited theoretically to a low efficiency by a certain thermo-dynamic law, as all heat engines are. The latter, as is well known, can not at best ever reach a moderately high efficiency. By "efficiency" is here meant the ability to convert as large a part as possible of the energy of the fuel into mechanical or electrical energy. On the other hand, however, this great advantage is more than counterbalanced by the fact that the fuel consumed in primary batteries is very much more expensive than that used in steam engines. The primary battery in its present form can not ever hope to compete with the steam engine and dynamo in the production of large quantities of electricity and no engineer would for a moment consider the replacing of the present engine and dynamo by primary batteries. But while this is true for the production of very large quantities of electrical energy, it is also true that for the production of smaller quantities the primary battery has decided advantages in economy of cost over the installation of an engine and dynamo plant.

It is even possible, although we may not live to see it, that at some future time a way may be found to get the energy out of coal directly in the form of electrical energy by means of some form of primary battery, thereby solving one of the two great problems at which so many engineers have been working. If this can not be done directly, there is open the possibility of an indirect method consisting of a primary battery in which the spent materials are again regenerated by means of coal, by a process which is not limited by that thermo-dynamic law. If one of these processes should at some future time be successful, the primary battery might have a fair chance of replacing the steam and gas engines.

The features of novelty of the Decker Primary Battery are the construction of the cell and its parts: chemically it is the usual bichromate cell. Some of these details are shown in the accompanying illustrations.

Fig. 1 shows a complete cell with the retaining cell removed; it has two porous cups P P and three graphite plates G G G . All these are secured together and to the bottom of the cell, so as to form mechanically a single piece. It also shows one of the corrugated graphite plates G_1 cut in two to show the corrugations. Also a porous cup P_2 cut in two to show the ribs inside. Also the terminal block B for the zinc plate Z_1 . Fig. 2 shows the channels at the bottom of the cells and the holes

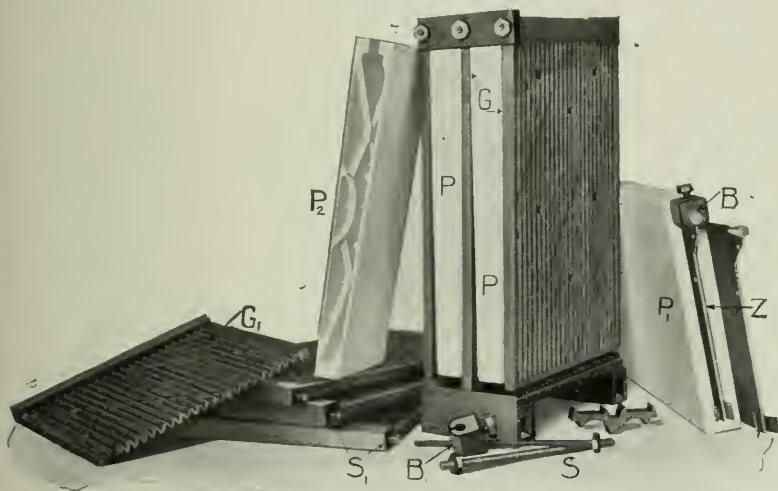


Fig. 1—Inside of one cell and the parts.

which connect with the porous cups. Fig. 3 shows a series of 16 cells with the two tanks of liquids below them, and the switch-board arrangements together with the pneumatic system of filling and emptying the cells. It also shows at the right hand bottom a very large cell having 10 zinc plates, which is shown here to-night.

The usual carbon plate is here made of graphite, molded first as carbon and then converted into graphite electrically. This makes it a better conductor and may perhaps increase the voltage slightly, as this cell on open circuit gives over 2.2 volts. The plate is corrugated and cross braced with diagonal ribs,

and it thus has a large surface and at the same time is strong. The upper part contains a brass rod or current collector imbedded in it nearly the whole width of the plate; this rod passes out through the side of the cell to the copper connectors and is therefore not exposed to the acid. It thus forms a low resistance connector for the graphite plate.



Fig. 2—System of channels in bottom of cells.

The zinc plates are made of rolled sheet zinc. They are amalgamated by a secret process which seems to be very effective, as I found in a test that there was no gassing and the consumption of the zinc was over 90% of the theoretical amount. These plates have a conical lug cast at the top, which fits into a conical hole in a zinc block secured permanently to the side of the cell by brass bolts leading to the copper connectors on the outside. The zinc

plates are therefore merely dropped into place and the connection is thereby made with the terminals without any screws or clamps, and as the only metal exposed to the acid is zinc, there is no local action there, which is often so destructive in other primary cells. The zincs are consumed very evenly and can therefore be used until they are quite thin. They are very easily replaced.

The zincs are in porous cups, which are of very ingenious construction. They are molded in two halves, with strengthening ribs on the inside surface. These halves are then secured together before baking. After baking, the outside surfaces are ground flat and to an even thickness. In this way, a very uniform, flat and strong cell is made, with thinner and more even walls than it would be possible to make by direct molding.

The retaining cell is made with channels in the bottom called the "irrigation system." One set of these communicates with the space around the graphite plates, while the other set communicates with the insides of the porous cups, through holes in their bottom edges. The two liquids are therefore introduced into their respective compartments from the bottom, through these channels. For a series of cells these channels are themselves connected to two main channels, thus enabling the whole series to be filled and emptied simultaneously from two tanks. The simplicity of this operation of filling and emptying is one of the chief advantageous features of the cell. The channels are made long and of small cross section, whereby they are given a high electrical resistance; the leakage of current or local action due to the cells being all in liquid connection with the same common tank, is thereby made negligibly small. By providing a large tank of solutions, the length of time during which the cell gives current with one charge of liquids may be made as long as desired. The liquids weigh only a fractional part of the whole, about 37% in one cell which I tested, and therefore by merely providing for two, three, etc., times the liquid, the discharge is made two, three or more times as long without increasing the weight very much. In this respect it differs radically from the storage battery.

The possible applications of such a battery are quite great. While of course it is not intended to replace the engine and dy-

namo, nor current or power from central stations where it is available, there are many other cases in which it is a question of either getting the current from a primary battery or not at all, as for portable purposes or to replace the storage battery. For instance, for a relatively small number of lights, or small motors, such as for fans, sewing machines, organs, piano players, dental engines, cauteries, etc. Or for train lighting. Or for launches, automobiles, etc.

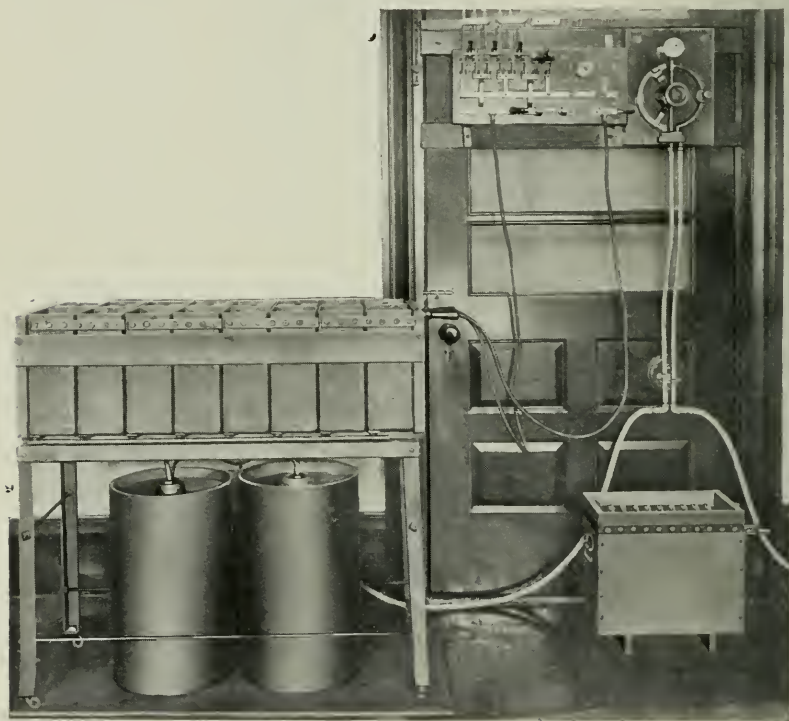


Fig 3—Sixteen cell battery with supply tank and controlling apparatus.

The cost was given by Prof. F. B. Crocker in a recent paper before the American Electrochemical Society as 35c. per H. P. hour for the zinc, acid and chromium salt. While this seems high, as compared with the cost of electrical energy from central stations, it should not be compared with it, as such a battery has its sphere of usefulness in places where current can not be obtained from central stations. The cost of the chemicals

in another form of primary battery, which is now used quite largely, he gives as \$5.30 for a H. P. hour. If such a price is not prohibitive for that battery, the cost of the present one would not only not be prohibitive but a very great reduction. In comparing this cost with that of storage batteries, the depreciation of the latter must be taken into consideration as it is relatively very high. In Prof. Crocker's paper this cost for the storage battery is said to be greater than the cost of the electrical energy for charging them, at 10c. per K. W. hour. It is contemplated, moreover, to regenerate the spent liquids from this battery electrically. I can vouch for the fact that the chromium salt can be very easily and thoroughly re-oxidized with an electric current and the zinc can be recovered and the acid set free quite thoroughly. Should it be found that this can be done cheaply and economically, the field of the primary battery will at once be very greatly extended, and it will then have very great additional advantages over the storage battery.

A much fuller description of this battery may be found in a paper read by Prof. F. B. Crocker at the recent meeting of the American Electrochemical Society and reprinted in the *Electrical World*, October 13th, 1906, page 724.

I had occasion to make a test yesterday of the large cell on the table, having 10 zinc plates and shown in Fig. 3, on the floor to the right. Briefly, the results were as follows: It weighs about 100 lbs., was discharged at 100 amperes, and ran for nearly 6 hours, during which the mean useful voltage was 1.64. It therefore yielded $1\frac{1}{3}$ H. P. hours or nearly 1 K. W. hour. About $4\frac{1}{2}$ of these cells would yield a H. P. of useful energy; they evidently occupied much less space than a boiler, engine and dynamo giving this power. The capacity was nearly at the rate of 10 watt hours per pound of complete cell or about 80 pounds per H. P. hour. As it is now discharging before you through this thick iron wire, heating it to whiteness, it is yielding about 400 amperes and the voltmeter shows that even with this very large current, it is not being overworked and is by no means short circuited. Probably no one present has ever before seen a single cell of a primary battery generating such a large power.

Compared with a standard storage battery for about the same duty, I find that the storage battery weighs about three

times as much, occupies about twice as much floor space, and more than twice the volume for the same power. In capacity per pound, the primary battery was three times as good for a single charge of liquid and when used with a tank containing several charges, this figure would be still better. Another advantage of the primary over the secondary battery is that it is not injured by an abnormally rapid discharge, nor by too prolonged a discharge, both of which are likely to happen while in use and both of which seriously injure most storage batteries.

I have tested many primary batteries, but have never yet seen one which was so well constructed mechanically and electrically, nor which was so light and compact as this one for the amount of electrical energy generated.

ELECTRIC FOUNTAINS.

It is somewhat strange that only within a few years has the electric current been employed in connection with the illumination of moving water, thus creating what is known in this country as the electrical fountain. The first to attract general attention because of its picturesqueness was that designed by MacMonnies, forming one of the principal features of the Chicago Exposition in 1893. This superb electrical display attracted such attention that the electrical fountain for exhibition purposes became quite popular. Current generated at Niagara Falls was employed for a series of water illuminations at the Pan-American Exposition, and electrical fountains were seen also at the World's Fair at St. Louis.

Really the term electrical fountain is a misnomer, for the current is usually employed merely for illumination, and not in forcing up the water from the basin or other form in which the fountain has been designed. This work is generally performed by the ordinary steam or hydraulic pump, but where the location of the source of supply is not sufficiently elevated to furnish the requisite pressure. Several American fountains have been constructed, however, where the electric current is utilized for power as well as for producing the light effects.

One of the largest and most notable fountains of this class in the United States is located in Willow Grove Park, in the suburbs of Philadelphia. It is designed entirely for amusement purposes, and the various shapes assumed by the water columns at nightfall, reflected as they are in the rays of the varied lights, form a spectacle which attracts thousands. The water required for this fountain aggregates 50,000 gallons every twenty-four hours, and is supplied by one large and one small pump, the larger being actuated by two 50 horse-power motors working on a 500 volt current.—D. A. Willey, in *The Electrical Age* for June.

Mining and Metallurgical Section.

(Stated Meeting, held Thursday, October 4th, 1906.)

Recent Progress in Metallurgy.

BY ALEXANDER E. OUTERBRIDGE, JR.,

Professor of Metallurgy, Franklin Institute.

In the annual address with which it has been my custom for some years past to open the autumn sessions of the Metallurgical Section of the Institute, I have endeavored to give a brief resume of the most notable achievements in metallurgy during the year, not only in practical applications of science to utilitarian purposes, but also to pay some attention to underlying theories and the ever changing views of physicists regarding the nature of ultimate particles of matter.

During the past year there have been few announcements of new discoveries in metallurgical processes, but there has been much discussion of new theories. We have been marking time, as it were, pausing to survey the field and to take more careful note of its topography. This does not mean that there has been no progress, but rather that the advance line which was at first erratic has been straightened and several blind leads have been abandoned.

In presenting new theories I have been careful to caution my hearers against accepting them unreservedly, for it seemed to me that theories which were so revolutionary as to upset all our preconceived notions of the stability of matter needed experimental demonstration of far more extended nature before they could safely be accepted as working hypotheses.

The subject is an abstruse one and in its present phase it appears to have little or no practical bearing, indeed it is fortunate that it is so, for the academic discussions now occupying the attention of many of the most noted philosophers of the

day, can be calmly studied without fear of disturbing any of our known metallurgical laws.

The classic investigations of Sir William Crookes on "Radiant Matter," published more than a quarter of century ago, paved the way for an entirely new conception of matter and seemed to prove one thing conclusively, viz: that particles of matter existed and were revealed in his high vacuum tubes very much smaller than the so-called atom, which was at that time thought to be indivisible. It is now believed, that such particles (electrons) are so minute that it would require perhaps one thousand of them to make one atom of hydrogen. This may be accepted without the necessity of adopting the views of certain enthusiasts who have proclaimed that matter, as we know it, is of a transitory character; that transmutation of elements is no longer a myth, and that the actual process of evolution of one element into another has been observed in at least one instance, viz: that of the change of radium into helium as seen in the spectroscope.

We are told that radium is an evanescent element, that a process of disintegration is continually going on among its atoms and calculations have been made of its probable period of duration as radium. Speculations of this nature are exceedingly interesting and valuable in preparing the way for further study, but, as I have previously said, they must be received with caution, and within the past few months Lord Kelvin and other noted scientists have disputed the sweeping conclusions that have been drawn from such incomplete evidence.

In studying the subject we are brought face to face with the fact of our ignorance regarding the true nature of matter, and also to a realization of how little we know of the forces of nature. If the kinetic energy contained in a mass of radium is sufficient to raise its own weight of water to the boiling point every hour, there is evidence of a stupendous force, the nature and power of which are unknown to us, and these are perhaps the greatest modern mysteries calling for future solution.

Leaving now these purely theoretical considerations let us look at the progress that has been made in metallurgy from a practical standpoint.

During the past twelve months the production and consumption of all metals has been phenomenally large. This may ac-

count, in part at least, for the paucity of new discoveries and inventions announced within that time. It is an economic fact that lean years of production make fat years of invention and *vice versa* and the reason therefor is apparent. When we are straining every nerve to obtain the greatest output from our furnaces or to keep abreast of our orders we have no time for experimentation and we are less concerned about cost of production than during dull periods. At such times we cling tenaciously to routine methods.

The rise and fall in the production of pig iron has long been regarded as a sure indication of the condition of business in all allied lines of industry, and, if this be true, all records in the past must fade into insignificance as compared with those of the year ending June 30th last, for in that period of time the production of pig iron in the United States amounted to no less than 24,432,106 tons, or more than two million tons each month.

Ten years ago the production was 8,623,127 tons according to the statistics of the American Iron and Steel Association. If we hark back to the year of our Centennial Exhibition we find that the total production of pig iron was only 1,868,961 tons in 1876. Those who are interested in such matters will no doubt remember the astonishment that was caused when the statistics of the production of pig iron in the year 1898 were published, showing a total of 11,773,934 tons, or nearly one million tons a month. Since that time we have advanced by leaps and bounds as the following table for ten calendar years will show:

PRODUCTION OF PIG IRON IN THE UNITED STATES.

1896	8,623,127 gross tons
1897	9,652,680 " "
1898	11,773,934 " "
1899	13,620,703 " "
1900	13,789,242 " "
1901	15,878,354 " "
1902	17,821,307 " "
1903	18,009,252 " "
1904	16,497,033 " "
1905	22,432,106 " "

The production of pig iron in the State of Pennsylvania in 1905 was 10,579,127 gross tons or 1,956,000 tons more than the total production in the United States in the year 1896, and nearly 1,000,000 tons more than in 1897.

Hardly less astonishing is the phenomenal increase in the production of open-hearth steel ingots and castings in the past few years. As stated in the *Bulletin* of the American Iron and Steel Association, the production of open-hearth steel ingots and castings in the United States in 1905 amounted to 8,971,376 tons, as compared with 5,908,166 tons in 1904, 5,829,911 tons in 1903, and 5,687,729 tons in 1902. Of the total production in 1905 7,815,728 tons were made by the basic process and 1,155,648 tons by the acid process, as compared with 5,106,367 tons by the basic process and 801,799 tons by the acid process in 1904, 4,734,913 tons by the basic process and 1,094,998 tons by the acid process in 1903, and 4,496,533 tons by the basic process and 1,191,196 tons by the acid process in 1902.

The production of basic open-hearth steel from 1902 to 1905 shows an almost phenomenal growth. Comparing the production in these two years of basic ingots and basic castings we find that the ingot production in 1902 amounted to 4,384,129 tons, as compared with 7,609,569 tons in 1905, an increase of 3,225,440 tons, or over 73 per cent., while the steel casting production in 1902 amounted to 112,404 tons, as compared with 206,159 tons in 1905, an increase of 93,755 tons, or over 83 per cent. The growth of the basic open-hearth industry has not been confined to ingots alone during the last four years but has been shared by the steel casting industry.

The total valuation of all iron and steel industries, including the product of foundries and machine shops, architectural and ornamental iron work, etc., in the United States was, according to the U. S. Census Report of 1900, nearly \$1,800,000,000, and as the output of pig iron has nearly doubled in the past six years, it is reasonable to suppose that the total valuation of all iron and steel industries has increased in similar ratio.

Five billion dollars a year is the estimated approximate value of the world's production of iron and steel annually and in this country the production and consumption have increased far more rapidly than elsewhere.

In 1876 the *per capita* consumption of pig iron in this coun-

try was under 120 pounds. In 1880 it was 205 pounds. In 1890 it had reached to nearly 283½ pounds.

It is stated that the consumption of iron per head in the United States in 1905 approximated 620 pounds as compared with about 68 pounds as the average consumption of the total production.

The remarkable increase in production of iron and steel in 1905 as compared with previous years has not been confined to the United States, but is world-wide. Our nearest neighbor, Canada, has taken the lead in relative increase of output, owing largely to the bounties paid by the Canadian Government on all iron and steel manufactured within the Dominion. The production of all kinds of pig iron in Canada in 1905 amounted to 468,003 gross tons as compared with 270,942 tons in 1904, an increase of 197,061 tons, or over 72 per cent.

The production of all kinds of steel ingots and castings in Canada in 1905 was much the largest in the history of the Dominion and exceeded by 254,665 tons that of 1904, an increase of over 171 per cent. The total output in 1905 was 403,449 gross tons as compared with 148,784 tons in 1904.

The production of pig iron in Great Britain in 1905 was the largest in the history of the United Kingdom, being 9,592,737 tons as compared with 8,562,658 tons in 1904, an increase of 1,030,079 tons, or over 12 per cent.

The total production of Bessemer steel ingots in 1905 amounted to 2,009,712 tons, against 1,781,533 tons in 1904, an increase of 228,179 tons or over 12 per cent.

The total production of open-hearth steel ingots in 1905 amounted to 3,879,748 tons, against 3,245,346 tons in 1904, an increase of 634,402 tons, or over 19 per cent.

The production of steel castings is never given in British statistics, nor is the production of crucible steel ingots. The production of crucible steel in Great Britain is estimated by the Secretary of the American Iron and Steel Association as amounting in recent years to about 100,000 tons annually.

In Germany and Luxemburg the production of pig iron in 1905 amounted to 10,987,623 metric tons, as compared with 10,103,941 tons in 1904.

The production of Bessemer and open-hearth steel ingots and

castings in 1905 amounted to 10,066,533 metric tons, as compared with 8,930,291 tons in 1904.

In France the production of pig iron in 1905 amounted to 3,076, 550 metric tons, against 2,974,042 tons in 1904.

The production of steel ingots and castings in 1905 is stated to have been 2,136,806 metric tons, as compared with 2,119,359 tons in 1904.

Italy, Spain, Sweden and Russia all produce iron and steel, but accurate statistics for 1905 are not yet available.

In most of these countries there has been undoubtedly increased production as compared with previous years, although in Spain there was a slight decrease in production of pig iron in 1905 as compared with 1904, and an increase in production of Bessemer and open-hearth steel castings amounting to over 22 per cent.

These data have been obtained from the Annual Statistical Report of the American Iron and Steel Association for 1905.

HIGH SPEED TOOL STEELS.

The use of ferro-alloys in the manufacture of "high speed" steel for cuttings tools has made great progress during the past year and has been extended in various directions with remarkable results. Large and costly milling cutters are now being made of this steel, as well as planer and lathe tools and drills. Improved methods of hardening and tempering this kind of steel have also been devised.

The advent of these tools has had already a far-reaching effect, not only on the time required for cutting metals, but also on the design and construction of machine tools. These must now be made much heavier and stiffer than formerly and the power required for driving them is correspondingly greater.

For example: In one instance where the output of a boring and turning machine was more than quadrupled by the use of high speed tools, it was found that the machine absorbed the entire driving power of the engine in the shop, whereas before the use of these tools this machine used about one-fourth of the whole power. In one of Mr. O. M. Becker's papers on "High Speed Steel in the Factory," printed in the *Engineering Magazine*, he says: "On steel speeds as high as 247 feet per minute (cut $\frac{1}{4}$ by $\frac{1}{8}$) have been attained for short times—and

this on 0.4 per cent. (carbon) steel. On such steel, however, 100 feet is all that can be desired for continuous performance, and 75 to 85 feet is in practice very satisfactory. In one instance 0.6 per cent. (carbon) steel is turned at a speed of 72 feet, feed 1-32, cut $\frac{3}{8}$, diameter of shaft 2 inches; but so far as reported nobody is able to do the same thing continuously—for the reason probably that in this case the job is done under exceptional conditions as to lathe, shape of tool, etc. Low carbon and machinery steel can be turned in large diameters and with light feed and cut as fast as 150 feet per minute, and sometimes even faster. In heavy cutting, say $\frac{3}{8}$ to $\frac{1}{2}$ inch depth by $\frac{1}{8}$ inch feed, 65 to 75 feet is all that can be recommended ordinarily.”

In cutting of cast iron there are so many variables that it is impossible to arrive at a fair estimate of the value of high speed steel, the degree of hardness or softness of the metal, the size of the piece, the amount of adhering sand and its condition, viz.: whether it is loosely attached to the surface or is “burnt in,” forming sometimes an abrasive surface similar to that of a grindstone, all have decided influence on the life of the tool.

I know of one instance in which certain cast iron bushings are being turned regularly day by day at a speed of 60 feet a minute which were formerly cut at about 30 feet a minute with the same feed and depth of cut. In this case, however, the iron in the casting is not quite the same as formerly, being now treated with a small quantity of a softening material in the ladle.

FERRO-ALLOYS.

The use of ferro-alloys in the foundry is likewise extending. The simple method first described in the address given before the metallurgical section of the Institute a year ago for softening iron for castings to any desired degree has been continued, with exceedingly beneficial results.

The speed of turning pulleys has been largely increased and the time required to complete the machine work upon them has been reduced, and in other light castings as well. In addition to the material improvement in the strength of the metal by this treatment, there is a decided decrease in shrinkage, so

that some castings of irregular shape which are difficult to make without cracking in cooling owing to unequal strains are now made without this tendency by this process. Other advantages accruing from the addition of a very small amount of high-grade ferro-silicon (containing about 50 per cent. of silicon) have been observed. Among these may be mentioned the cleaning action upon the molten metal which the alloy effects by its deoxidizing influence. Singularly also it is found that commercially pure silicon does not produce these results, neither does the ordinary grade of ferro-silicon, containing about 20 per cent. of silicon.

Fig. 1 shows the fracture of two test bars cast from a ladle of untreated iron. The upper piece was cast in green sand

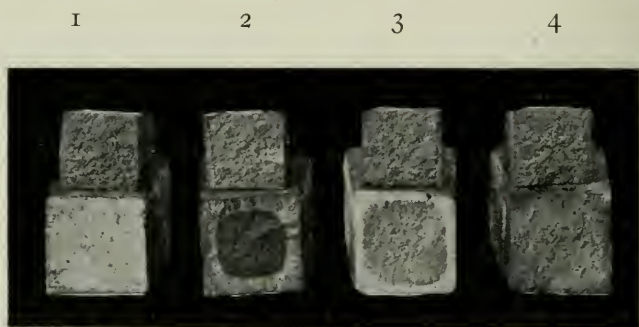


Fig 1 - Softening effects of ferro-silicon added to a ladle of molten metal.

1"×1"×15" and was an ordinary transverse test bar. The lower piece was cast in a heavy iron cup in order to very rapidly cool the metal. The upper test piece is perfectly grey and easy to drill. The lower one is perfectly white and can not be drilled with an ordinary steel drill.

Fig. 2 shows the fracture of two similar test bars poured from the same iron after addition of 0.3 per cent. of silicon in the form of high grade ferro-silicon (50% Si.) added in the ladle. Note the marked reduction in depth of chill in the sample cast in the iron cup.

Fig. 3 shows the fracture of two similar test pieces from the same iron after adding 0.5% silicon in the ladle. The "chill" is still further reduced.

Fig. 4 shows the fracture of two similar bars from the same

iron after adding 0.8% silicon in the same manner. The chill in the sample cast in the iron cup is almost entirely absent.

The samples cast in sand are all perfectly grey, but there is an appreciable difference in the fracture, the treated metal showing softer iron than the untreated sample.

The metal selected for this particular test was comparatively low in silicon, consequently having comparatively high chilling property, but this fact would never be suspected from an examination of the fracture of the test sample cast in sand. Very few practical foundries are aware of the large variation in chilling property of their iron, sometimes of presumably similar grades, melted on different days, or even of the wide variations which may occur in different portions of one heat. The chill cup test here shown is an invaluable instructor in this matter, and without its aid the beneficial effects of adding high grade ferro-silicon to molten cast iron could not have been so readily detected and exhibited. These chill magnifiers have been used with great benefit in daily practice for more than twenty years. They are far more effective than the ordinary chill tests made in car wheel foundries. Such tests are only applicable for very high chilling iron, while the cup tests here described are only intended for use with comparatively low chilling irons.

In the case of pure silicon the specific gravity of the material is too low and its melting point too high to permit it to become incorporated with the molten iron in the ladle, in the other case the proportion of silicon is too low to permit a sufficient amount to be dissolved in the iron to produce a radical change in its quality without causing dull iron in the ladle.

There is no doubt that when the merits, simplicity, certainty of action and other advantages of this process of treating molten iron in the ladle are better known and appreciated it will come into very extensive use, for it enables the founder to modify the character of his iron to suit individual castings, a matter of considerable importance and value. This is accomplished without expense, for the cost of adding silicon to the iron in this manner is actually less than by the usual method of adding an equal amount of silicon to iron in the form of pig iron comparatively high in silicon added in the cupola. For example, pig iron containing 6 per cent. of silicon costs at the present time, let us say, \$22.50 per ton, and we may estimate for

comparative purposes \$3.75 per unit of silicon; ferro-silicon containing 50 per cent. silicon costs at the present time in powdered form \$100 per ton, or \$2 per unit of silicon on the same basis of calculation.

Furthermore, there is no loss of silicon when added in the ladle as there is when melted in the cupola, and this partly accounts for the fact that a given quantity of silicon, when added in the ladle, is much more effective as a softener than the same quantity charged into the cupola. Silicon added in the cupola always weakens the iron, while silicon added in the ladle always strengthens it.

STEEL-HARDENING METALS.

The Mineral Resources of the United States for 1905, soon to be issued by the Department of the Interior, U. S. Geological Survey, will contain a special chapter on the production of Steel Hardening Metals, including Nickel and Cobalt, Chromium, Tungsten, Molybdenum, Vanadium, Titanium and Uranium, prepared by Mr. Joseph Hyde Pratt, from which the following data have been obtained:

During 1905 the total production of the steel hardening ores and concentrates in the United States amounted to 922 short tons, valued at \$288,836. Of these tungsten was by far the most important as appears in the following table of production of Steel Hardening Metals in 1905:

	Short tons.	Value.
Chromium	25	\$375
Nickel and Cobalt.....	90	19,410
Molybdenum.....		
Titanium		
Tungsten	803	268,676
Uranium and Vanadium.....	4	375
Total	922	\$288,836

During 1905 there was no actual production of any metallic nickel or cobalt from native ores; at present practically all of the nickel used in the United States is obtained from matte imported from Canada and from ore imported from New Caledonia, the former furnishing by far the larger amount. The total quantity of nickel compounds of all kinds imported and

entered for consumption in the United States in 1905 was 31,072,206 pounds, valued at \$1,962,131, and of cobalt oxide 70,048 pounds valued at \$139,377.

The very general use of tungsten for alloying with steel, up to 15 per cent. and over, in the manufacture of high speed cutting tools has created a new demand for that metal and a corresponding increase, both in production and price. In 1900 the total production of tungsten concentrates in this country amounted to 46 short tons, valued at \$240 a ton. In 1905 the production was 803 short tons, valued at \$334.50 a ton. Tungsten ores are also imported free of duty and it is, therefore, impossible to obtain statistics for them. Ferro-tungsten-chromium alloys were imported to the value of \$13,525 in 1905.

The production of titanium was entirely from Virginia in 1905 and was about 50 tons in amount.

A United States patent has recently been issued for the treatment of car-wheel iron in the ladle with powdered Rutile, the chief ore of titanium, for the purpose of increasing the hardness of the chilled tread. Without having had any experience with this process, I am unable to express an authoritative opinion regarding it, but on general principles, I should be inclined to doubt the efficiency of adding any ore to molten iron in a ladle.

The results of independent tests made by different investigators of the remarkable influence of small quantities of Vanadium in increasing the tensile strength of steel is likely to create a demand in the near future for that metal. The production of Vanadium and Uranium concentrates in 1905 amounted only to four tons, obtained from Colorado and Utah. There was, however, considerable ore mined which was not concentrated at all, but was stored waiting the erection of concentrating mills. The total tonnage of ore reported to the Geological Survey was 2,081 short tons.

A plant is in process of erection for the treatment of the vanadium sandstone found near Telluride, Colorado. A plant is projected at Castledale, Utah, in which to reduce the uranium ores of the vicinity by a nitric acid process. At Cedar, Colorado, a concentrating mill was recently built for treating the vanadium and uranium ores of that region. With the installation of these mills there should be a large increase in the

production of vanadium and uranium ores to supply the probable demand for alloying with steel.

NICKEL-VANADIUM STEEL ALLOYS.

An interesting series of investigations on nickel and steel, vanadium and steel, and nickel together with vanadium in small quantity in steel have been published by M. Leon Guillet in the *Revue de Metallurgie*.

It was found that in the perlitic steels containing 0.2 per cent. carbon and from 2 to 12 per cent. nickel, the tensile strength and the elastic limit were both materially increased by the addition of small percentages of vanadium. A steel containing 0.2 per cent. carbon, 2 per cent. nickel and 0.7 per cent. vanadium showed a tensile strength of 91,000 pounds per square inch, an elastic limit of 70,000 pounds, and an elongation of 23.5 per cent. With 1 per cent. of vanadium, the ultimate tensile strength increased to 119,500 pounds, and the elastic limit to 91,000 pounds, the elongation falling slightly, viz: to 22 per cent. A nickel steel of 0.2 per cent. carbon and 12 per cent. nickel gave, with 0.7 per cent. vanadium, a tensile strength of over 200,000 pounds per square inch, and an elastic limit of 172,000 pounds, the elongation being 6 per cent., while with 1 per cent. vanadium the tensile strength rose to 220,000 pounds, and the limit of elasticity to 176,000 pounds, the elongation remaining unchanged. When the vanadium content is increased above 1 per cent. the tensile strength falls off, and the material begins to show evidence of brittleness. Similar effects are produced with steels of higher carbon, but in lesser degree.

The practical conclusions drawn are that the addition of vanadium is of value to steels containing from 2 to 12 per cent. of nickel, and in no case should more than 1 per cent. of vanadium be used. The result is to increase both the tensile strength and the elastic limit, especially if the steel is tempered by heating to about 850° C. and cooled in water at atmospheric temperature. These data have been obtained from a review of M. Guillet's paper in the April issue of the *Engineering Magazine*.

BLAST FURNACE SLAG CEMENT.

In my address a year ago I called attention to the utilization of waste products in metallurgical works. One of the most recent developments in this direction is that of making cement of good quality from blast furnace slag, a waste product. Hitherto this material has not been found suitable for the manufacture of Portland cement owing, I believe, mainly to the presence of sulphur, but it is now stated that a process has been found for eliminating this objectionable element. When we realize that the output of cement in the United States in 1905 was over forty million barrels (an increase of 8,427,051 barrels over the product of the previous year) and that there are vast accumulations of slag at every blast furnace, the importance of the discovery of a process of utilization of this waste material as cement will be apparent. Referring to the subject in a recent issue *The Manufacturer* says:

“Changes of vast importance to the cement industry of the country are imminent, growing out of the experimentations, of the United States Steel Corporation, and it is stated that the corporation is on the verge of becoming the dictator in the cement industry, says a Pittsburg dispatch. It has worked out at the Chicago blast furnace plant a process for utilizing the waste product of the blast furnace, commonly known as slag, in the manufacture of fine grade cement. This matter has been experimented with for years and has always seemed feasible, as the chief portion of slag is the lime flux that comes from the large use of limestone in blast furnace practice. It is stated that a process has been found which fully fulfils all expectations, and it is the intention to erect a plant at once at the Carrie furnaces across from Homestead to be followed by plants at Braddock, Donora, Sharon, Duquesne and the other points where blast furnace slag has been accumulating as a nuisance for many years.”

Officials of the United States Steel Corporation are forming a number of subsidiary concerns to the new Indiana Steel Company, at Gary, Ind., which will become potent factors in the general operation of that new industrial centre when all is completed. One of the most significant and interesting of these that has taken form during the last week is to be known as the

Universal Portland Cement Company. It has a capital of \$1,000,000, and its plans, while only vaguely outlined thus far, are understood to contemplate the manufacture of a slag cement out of the furnace slag coming from the new blast furnaces to be built in the new town.

The Steel Corporation has been slow to give attention to the by-product of its furnaces, though an enormous consumer of cement itself. It has spent annually millions of dollars to dispose of its waste slag from blast furnaces, and is now having no little difficulty in getting rid of this material. In the mills and furnaces of the Illinois Steel Company there has been established a cement department which has been running with more or less success, but it has been hindered by the difficulty of eliminating sulphur from the slag. Its presence in the cement causes a disintegration after it has hardened unless set under and left under water.

Recently, it is said, the Steel Corporation has come into possession of processes that will eliminate sulphur during the process of making the cement. This will give the corporation a practical cement for all purposes with only the base cost of making it. The saving will be enormous, as there is no investment for cement deposits, nor for much machinery that is necessary for the manufacture of the ordinary rock cement. The raw material is a pure waste, and, passing through a process of extraordinary short duration of time, becomes a product of great commercial value.

The plant is understood to be one of a number that will eventually be put up. Some may be built in Pittsburg, where they can take over the slag from the scores of blast furnaces of the corporation in this vicinity.

Slag or puzzolan cement has been made to some extent for several years past at a few blast furnaces in this country, the product being chiefly utilized for certain parts of their own construction work. The total output in 1905 from nine works was 382,447 barrels. A characteristic analysis of puzzolan cement from the Ashland Iron Co., Kentucky, which is claimed to be the finest slag-cement plant in the country, is as follows:

Silica	35.72
Iron oxide	.84
Alumina	9.72

Lime	45.42
Magnesia	2.85
Sulphur	1.42
Loss on ignition	3.66
Undetermined	.37

 100.00

In reply to a recent inquiry for the latest information on this interesting and important subject, I have received the following statement from Mr. Robert W. Leslie, Vice-President of the American Society for Testing Materials, who is a large manufacturer of Portland cement:

"Broadly speaking, slag is utilized for the manufacture of cement in two ways:

"First: In the manufacture of Puzzolan or Slag Cement. This is produced by grinding slag mechanically with slaked lime to an impalpable powder. This, as you will notice, is a mechanical mixture, and when water is added to it, with sand, it will set and make an admirable mortar.

"Second: Portland Cement. In this case, which is the practice of the Illinois Steel Co., at their Geary plant and will be practiced at their new plants, slag is granulated and is ground to an impalpable powder with ordinary limestone (carbonate of lime) and this impalpable powder is fed into revolving kilns known as rotary kilns, where it is burned to clinker (incipient vitrification) by flames produced by the injection of pulverized coal into the kilns. This clinker is ground again to impalpable powder, and is the Portland cement of commerce.

"During the present year of 1906 the Illinois Steel Co., at their plant at Geary, will turn out from a million and a quarter to a million and a half barrels of Portland cement made under the latter process, and at their works at South Chicago, three or four hundred thousand barrels of puzzolan, made under the old process. There is no patent on either of these processes."

An interesting improvement in the pig iron industry, described in my address a year ago, to wit: the Gayley Dry-Air Blast Process, is worth noticing. The process has proved itself to be highly economical and will doubtless be largely introduced. During the year 1905 there was produced 276,000 tons of pig iron by this method, and several large plants are now in course of construction.

ALUMINO-THERMICS.

In my address a year ago I described the remarkable process discovered by Professor H. Goldschmidt, of Essen, for the instantaneous production of intense heat (approximating 3000° Centigrade) caused by the reaction between the metal aluminum in granular or powdered form and iron oxide, which has been applied successfully on a large scale in sundry metallurgical operations, notably, in welding of steel rails *in situ*, mending broken stern posts of vessels, etc., and in the production of pure metals and alloys. In order to obtain the most recent information regarding the progress during the year past the Secretary of the Institute, at my suggestion, wrote to the Goldschmidt Thermit Co. and received from the Vice-President the following reply:

"The progress made by the alumino-thermic process is naturally more of a commercial than a technical progress. The changes made in the manipulation have all been in pursuance of more simple methods, such as recommended themselves in actual practice in the field. For instance, for rail welding, a simplification consisted in cutting down the size of the mold boxes that surround the joint, to a point flush with the head of the rail. The former upper part of the molds, which contained the receptacle for the slag, has been replaced by a separate, so-called "slag box," made of cast iron, which sits tightly on the top of the mold boxes and can be easily removed after the pour, drawing the slag with it. In this manner it is possible, when welding under traffic, to allow cars to run over a welded joint without removing the mold, and to obtain greater speed in the welding operation.

"The shape of shoe for rail welding has also undergone modifications and it has been found that by checking the flow of metal under the base of the rail, a sensible improvement in the strength of the weld is obtained.

"More numerous operations on a large scale have provided welcome opportunities of observing the flow of thermit steel in large quantities. For such operations it is now made a rule to pre-heat the casting after the mold is in place, by driving air under forced draft through coke placed in a basket over the mold, the air passing in at the riser and out of the gate. This

system brings the part to be welded to at least dull red heat and assures the mold to be absolutely dry. The molds for such large operations must be made of 35 parts fire-clay and 65 parts sand. For such large operations the use of an addition of higher carbon iron, in the shape of rivets, is advisable, in the proportion of 20 to 25% of the amount of thermit brought to reaction.

"Among the more important operations of a large nature must be mentioned the welding of the keel bar of the 'Star of Russia,' December 28, 1905, in Oakland, Cal.; the welding of the stern post of the steamship 'Puritan' (1547 tons), April, 1906, in Chicago; the welding of the stern post of the steamship 'Alaska' (1288 tons), Buffalo, in May; the stern post of the tug boat 'Murrell' (311 tons), Boston, in July; the main shaft of the stern wheelers 'J. D. Peters' and 'Capt. Weber,' at Stockton, Cal., and of several large dredger bucket arms—one in particular, on a dredger bucket weighing 12 tons, with six cubic yards capacity.

"For welding wrought iron pipes, tubes and rods, a simplification of the process has been obtained by substituting cast iron for sheet iron molds. The dimensions of these molds have been tested out for all sections up to 4 inches in diameter.

"The process is now in regular practice by some thirty street railways for welding their rails, by a large number of railroads for repairing locomotive engine frames and by all the larger steel casting concerns, for repairing castings and increasing the temperature in their ladles and risers."

PRODUCTION OF ALUMINUM.

The metal aluminum, once called "the metal of the future," is now entitled to a high place in the list of economic metals of to-day, the production having increased from a few pounds twenty-five years ago to about 5,000 tons in 1905. Owing to the discovery of the electrolytic method of refining the cost of the pure metal has declined from \$8 to less than 40 cents a pound.

The great increase in production of this metal, which supercedes copper for many purposes, as in the manufacture of various alloys, also for conducting wires for powerful electric cur-

rents, etc., is all the more remarkable in view of the enormous increase in production of the latter metals.

Notwithstanding the fact that nearly all of the commercially pure metal aluminum is produced by one company in this country, and that there is no competition, the price has been reduced to a figure which enables it to supplant copper for many industrial uses; the high price of copper has, of course, widened this field materially. The electrolytical method of reducing the metal from bauxite—the only available ore—is too well known to need description here. Very recently an entirely novel method of producing aluminum has been devised, which does not depend upon bauxite and makes available vast deposits of clay, or alumina, which are not applicable to the electrolytic method. The following brief description of this new process is taken from a very interesting popular article on "High Temperatures and Modern Industry," in the October issue of *Harper's Monthly Magazine*:

"Thanks to Moissan and his methods nearly every metal has its carbide. For example, there is aluminum carbide, which Moissan prepared some years ago by heating in the electric furnace a mixture of kaolin and carbon. It constituted a body of beautiful yellow crystals which were apparently useless. Now, after all these years, comes the present discovery that this Al_4C_3 , so produced, on being heated with alumina (the oxide of aluminum) yields the pure metal and carbonic acid gas—a wholly new and elegant method of extracting aluminum, and one, obviously, of immense value when developed."

A practical method of plating aluminum on iron would be a very valuable discovery. During the past year two different methods have been published in technical papers, and being skeptical regarding their efficiency, I sent the formula of one to Dr. Joseph W. Richards, who is in charge of the Department of Metallurgy and Mineralogy at Lehigh University and a leading expert on aluminum; his reply to my inquiry is as follows: "The process of plating aluminium is new to me. It recalls the effort to plate Al. on the City Hall tower (Phila.), using Al. anodes and tin salts in the electrolyte. Of course aluminium went into the solution, but *only tin came out*. The same would occur with the electrolyte of $\text{Na}^2\text{S}^2\text{O}^3$, ZnCl^2 and NH^4OH . Zinc would come out as long as there was any

in the bath, while the aluminium would accumulate in the solution." The other process, devised by a Frenchman, M. Geroux, uses neutral copper acetate as the only metallic salt in the electrolyte. I have not been tempted to test it. In my address last year I called attention to the fraud that was perpetrated years ago on the City of Philadelphia, when large sums of money were paid ostensibly for plating the iron work of the great tower on the City Hall with aluminum. Irreparable damage by rusting of the exposed metal has resulted therefrom.

PRODUCTION OF COPPER.

The increase in the production of copper in the United States in the past five years is quite as remarkable as the increase in production of iron, being in the present year at the rate of over one hundred thousand tons greater than the average for the previous five years.

In 1880 the production in the United States amounted to 25,000 tons, or about one-sixth of the world's output. In 1905 the production is reported at 413,070 tons, or more than one-half of the total output. The mines in the Lake Superior region contributed about one-fourth of the total production in this country.

The following table, giving figures for the year 1880 and 1905, is taken from a recent article on "The World's Copper Output," by John B. C. Kershaw, F. I. C., F. S. S., printed in *Cassier's Magazine*, September, 1906:

Country	Production.	
	1880.	1905.
United States	25,010	413,070
Chili	42,916	29,165
Portugal and Spain.....	36,313	44,810
Germany	10,800	22,160
Australia	9,700	36,560
Cape of Good Hope.....	5,038	7,325
Japan	3,900	35,910
Russia	3,300	8,700
Norway	2,426	6,295
Peru	600	8,625
Mexico	400	65,185
Canada	50	20,535
Remaining countries.....	13,506	10,470
Totals	153,959	708,810

The enormous increase in production of copper has been due partly to the increased demand for the metal since the advent of electric power for all purposes. Coincidentally with the increased production has come an increase in price of refined copper and decrease in cost of the process of refining. Mr. Kershaw says: "The average profits of the refining companies in recent years must, therefore, have amounted to over £15 per ton, and the aggregate profits of the producing industry in twenty-five years to the enormous total of £135,000,000 (\$675,000,000) on a total production of 9,000,000 tons of copper.*

In 1880 the electrolytic method of refining was in its infancy, the total amount thus refined being 2,000 tons as compared with 350,000 tons in 1905.

In 1880 no refining by this method was recorded in the United States, while in 1905 the output of the electrolytically refined copper in the United States was 304,000 tons as compared with 46,000 tons in Europe.

The electrolytic process of refining copper is one of extreme beauty and simplicity. The process depends upon the passage of an electric current between two sheets of copper suspended in a tank containing copper sulphate in solution. As only the copper in the crude metal can act as a carrier of the current under the conditions obtaining in the vat, the impurities of the metal are left behind, and pure copper alone is deposited on the sheet of metal by which the current of electricity leaves the vat.

GREAT INCREASE IN PRODUCTION OF GOLD.

The output of gold has quadrupled in the past twenty years, and stands, as regards its rate of development, above many other metallurgical industries. In a recent résumé of two papers by M. de Launay, an eminent French mining engineer, and professor at the Ecole Supérieure des Mines, published in the *Revue Générale des Sciences*, the *Engineering Magazine* says: "The enormous increase in the rate of production of gold is one of the remarkable industrial and economic phenomena of

*In October, 1904, copper was quoted in New York at 13c per pound, in October, 1905 at 17c and on October 15, 1906, at 22.62 per pound. Still higher prices are not unlikely in view of the extraordinary demand.

the present time. The curves representing the production of other metals have shown upward tendency, more or less marked, but the line showing the gold production of the world shows such a remarkable upward tendency that at times it almost approaches the vertical. When the curve is separated into its three components, representing respectively the three principal sources, the Transvaal, the United States and Australia, it is seen that there is a marked similarity between them, interrupted only by the break due to the war in Africa. The figures for the year 1905 given by M. de Launay, in francs, are: Transvaal, 524 millions; Australia, 432 millions; the United States, 436 millions; a total of 1,392 million francs, or about 278 million dollars. These three countries produce 72 per cent. of the world's total, which reaches 1,908 millions of francs. * * * It is largely because of the improved process of extraction that the production of gold has increased at the rates already given, since it is by the wholesale application of modern methods that the lowest grade deposits can be commercially worked. Thus, in a large and accessible mine it is assumed, on an average, that the material can be treated for about 12 francs per ton. Very often, however, the cost reaches double this figure, according to location and operative difficulties. In the great workings in Dakota, on the contrary, the cost has fallen as low as 2.10 francs per ton, and at the Alaska Treadwell mine to the minimum of 1.12 francs.

It is interesting to recall the fact that many years ago the assayers of the mint (Eckfeldt and DuBois) found that gold was uniformly distributed in very minute division in the bed of clay underlying the city of Philadelphia, and they made the astounding statement in a paper published in the Proceedings of the American Philosophical Society that there was more gold underlying the streets of the city than had been taken at that time from California and Australia combined. There was enough gold (according to their calculations) in each brick, if hammered into leaf, to make a sheet of gold two inches square and about one-three hundred thousandth of an inch thick. It was, of course, stated that the cost of extracting the gold would be far in excess of its value, but modern methods of refining low-grade ores had not been discovered at that time, and it may come to pass that the alluvial gold in the clay may

yet have a market value. This, however, is a mere speculation at present. Certain it is that the vast increase in production of gold in modern times is due to the economical methods of reclaiming the gold from lean ores that had no value whatever at the time this interesting paper was published.

DECLINING PRODUCTION OF SILVER.

While the output of gold has doubled in the past ten years in this country, that of silver has shown a slightly declining tendency. In 1900 the output of our mines, according to the report of the U. S. Mint Bureau, was 57,647,000 troy ounces, having a coinage value of \$74,553,495, while that of 1904 was 53,603,000 ounces, having coining value of \$69,303,319.

The decline in production of silver has not been due to exhaustion of silver mines, but to the low price of silver. There are many silver mines now closed on this account which will again become active when the price of silver shall advance. The indications are that the bottom price for silver has been reached and that its value will gradually increase.* A very large proportion of the silver marketed in recent years has been a by-product from the refining of lead and copper, and I have been informed by a mining engineer of large experience that the actual cost of fine silver is, in some of these operations, less than ten cents an ounce.

The de-monetization of silver by most of the nations naturally helped the decline in value of this commodity; but, on the other hand, the low price has largely increased the consumption in the arts. Sterling silver is now replacing silver plated ware to a great extent, and the increased demand from manufacturers has created an enlarged market for silver. New methods of mining and refining have likewise reduced the cost of production, and the result of these conditions will, in all probability, be an increased annual output in the future.

The most notable advance in this direction is the great ex-

*This statement was in type when the latest sensational advance in price of silver occurred, when the U. S. Treasury Department purchased 150,000 ounces of silver for the Denver Mint at 70.13 cents per ounce, the highest price paid since the repeal of the Sherman Silver Purchasing Act in 1893. The price paid by the Government one year ago was 62.33 cents per ounce.

tension of the cyanide process to silver ores now taking place, especially in Mexico. Particulars relating thereto may be found in a paper by Prof. J. W. Richards in *Electrochemical and Metallurgical Industry*, September, 1906.

The world's product of silver was estimated at 173,000,000 ounces in 1901; the present annual production is believed to be about 3,000,000 ounces less than that, but, for reasons here given, it seems probable that silver will now join the procession of metals in increased production in the future, barring unforeseen commercial panics or other causes affecting the general prosperity of the nations.

PRODUCTION OF OTHER METALS.

Zinc.—There was a fair increase in the production of spelter during the year 1905, the increase over 1904 being 17,147 short tons. The production has more than doubled since 1897, when it closely approximated 100,000 tons. The output in 1905 was 203,849 short tons, as against 186,702 tons in 1904. For the first time in the history of the zinc industry in the United States the consumption of spelter crossed the 200,000 ton mark. The total world production in 1905 was 727,141 short tons as against 693,022 tons in 1904.

Antimony.—The output in the United States in 1905 amounted to 3,240 short tons, the largest in three years, and only twice in the history of the trade was there a larger annual production. Notwithstanding the fact that there are good deposits of ore in several of the Western States, we mined no antimony in 1905. The entire market is supplied from antimony that is recovered as a by-product in refining base bullion which contains from 20 to 40 per cent. of antimony and by imports from foreign countries.

The chief use of antimony is for alloying with other metals, type metal containing from 17 to 20 per cent.; pewter a little over 7 per cent., and Britannia metal 10 per cent. of antimony. Aluminum-antimony alloys are also being made. Anti-friction metals for high-speed machinery contain antimony.

Some of the data regarding production of various metals have been obtained from advance chapters of Mineral Resources of the United States for the calendar year 1905, to be

issued by the Department of the Interior and were furnished by the Director of the U. S. Geological Survey.

Tin.—The advance chapter from Mineral Sources of the United States states that during the year 1905 there was no actual production of metallic tin in the United States, the only production being an insignificant quantity of ore from the placers of Buck Creek, Alaska. There was no output from the lode claims of the York region, Alaska; none from South Carolina, although 18 tons had been washed from the residual placers at Gaffner, in the northern part of the State in 1904; nor was any production reported from the Black Hills region of South Dakota and Wyoming. Prospecting was actively carried on in the Lost River Valley of the York region, where larger quantities of tin ore were shown to be present than had been known, and smaller veins were found at several points in the vicinity of the original discovery. No new occurrences of tin are known to have been found in the United States in 1905. The total world's production of tin in 1905 was a trifle over 100,000 short tons and was about the same as that of 1904. During 1905 the United States imported 44,188 short tons, about 43 per cent. of the total visible output. The price of tin at the opening of the year was 29.05 cents; since January 1st, 1906, the price has risen greatly, reaching 48½ cents on the New York market. One of the interesting late developments in Cornwall, England, is the proposed reopening of abandoned tin mines, owing to the present high price of tin. Cornwall has produced tin for more than 2000 years.

The following table shows the approximate tin output of the world during the year 1905:

Country.	Short tons.	Per cent.
Australia	5,028	4.88
Banka	11,155	10.81
Billington	2,715	2.63
Bolivia	13,646	13.23
Cornwall	5,040	4.88
Malay States	65,565	63.57
Total	103,149	100.00

The rise in price of tin has caused a search for substitutes in the manufactures. In an article on substitutes for tin by L.

Parry in *Mining Jour., Rwy. and Com. Gaz.*, London, June 2, 1906, various substitutes are given. Chief among these is the metal aluminum. Mr. Parry says: "The diminution in the price of aluminum, the practically limitless supply of raw material, and the physical properties of the metal are facts which must at once appeal to the technical imagination, and point to this—the most abundant of the metallic elements—as a possible substitute for tin. At the same time it is not the only metal which has to be considered in this connection."

CONCLUSION.

It has been my endeavor to show, as briefly as possible, the marvellous advance that has been made during the past few years in the production of metals all over the world, indicating wide-spread prosperity in the metallurgical world, also the lesser degree of progress recorded of new discoveries in metallurgy during the past twelve months.

It has, of course, been impossible to do more than to take a hasty glance at a few of the most striking developments. We have attained in this country during the past twelve months the highest pinnacle of activity and prosperity ever recorded; whether this shall prove to be the highest attainable point, the future will show.

PREMELTING ADDITIONS TO THE OPEN HEARTH BATH.

The Carnegie Steel Company has recently acquired two patents issued to William B. Hughes, formerly of Philadelphia and now with the Wellman-Seaver-Morgan Company, Cleveland, covering improvements in open hearth steel practice. The procedure consists in premelting, outside of the open hearth furnace, oxide of iron and mixing it with lime to form a highly oxidizing basic slag, the molten slag being added to the bath of molten iron on the hearth of the furnace. It is claimed that the improvement permits of working furnaces at their maximum capacity, renders unnecessary the use of very large furnaces, and saves the time heretofore required for heating the basic additions when charged cold on the hearth of the furnaces. The addition of the molten basic slag to the bath removes silicon and phosphorus from the iron without risk of injury to the hearth or lining, such as may result when the ore and lime are melted in the furnace. It is also stated that the molten slag acts more uniformly than if its constituents were charged into the furnace cold, and in the subsequent reaction and discharge of slag the loss of uncombined oxide, which is sometimes carried off mechanically, is prevented.—*Iron Age.*

FREE ANALYSES AND ASSAYS OF MINERAL BY GOVERNMENT.

Among the numerous mistaken ideas that prevail regarding the functions of the Government one of the most general is that some department in Washington is prepared to make analyses or assays of anything in the shape of a mineral which may be submitted by any citizen of the country. Naturally, the Geological Survey is credited with this function and as a result not a day passes without the receipt of a dozen or more requests for such work. These requests are acknowledged with the statement that the Survey has neither the legal authority nor the available funds to make indiscriminate analyses or assays for private parties.

A small appropriation is made "for chemical and physical researches relating to the geology of the United States," but this is inadequate for the absolutely necessary chemical and physical work required by the geologists in connection with these investigations. Even if the appropriation were sufficient to provide ample facilities for making private analyses it could not be used for this purpose unless such analyses were directly contributory to the solution of some geologic problem. Fortunately, a large proportion of the specimens submitted can readily be determined by means of simple tests and careful visual examination. Such a determination is always made wherever possible, and the person who submits the mineral is given all the information available regarding it. In most cases this is quite as satisfactory as the result of an elaborate and expensive analysis would be. A large proportion of the specimens submitted are absolutely worthless, some have a commercial value only when occurring in large masses and convenient to transportation, while a few afford clues to new occurrences of rare and interesting minerals, which are of great value in connection with the regular work of the Survey.

It is not expected or desired that the practice of sending in minerals for determination should be discontinued, but it is best that the public should not rest under a misapprehension as to what can be done with them.

DANGER OF HIGH CHIMNEYS IN EARTHQUAKE REGIONS.

The experiences of the recent earthquakes have forcibly emphasized the marked advantages of the short steel stack, which is all that is essential with a mechanical draft installation. High brick chimneys have proved to be sources of danger. Their wrecking on all sorts of buildings in the stricken region was no inconsiderable factor in the general destruction. Most of the power stations around San Francisco came through in pretty fair shape, save for the stacks, thanks to the fact that most of the plants were fairly well built and did not carry their weights too high. After this experience tall chimneys may be counted on as pretty certain to go in a severe earthquake. On the other hand, there is much to be said for short stacks and forced or induced draft. This construction, which has entered into recent equipment in Japan, suggests still another of the advantages of this modern system of draft production.—*Iron Age*.

Section of Physics and Chemistry.

(Stated Meeting, held Thursday, May 10th, 1906.)

Notes On Some Recently Devised Tests.

BY HENRY LEFFMANN.

Precipitant for Nitric Acid.—The fact that, until very recently, no normal nitrate sparingly soluble in water was known, has prevented the determination of nitrogen in this form by direct methods. Although some of the indirect methods have been fairly convenient and satisfactory, it is always desirable to have a direct process.

M. Busch (*Ber.*, 1905, 861,) found that a complex derivative of pyrrol forms a nitrate which is so slightly soluble in cold water that it can be satisfactorily used as a precipitant for nitric acid and nitrates. The substance has been termed "nitron" by Busch, to avoid the long systematic title (diphenyl-endanilo-dihydrotriazol.) It is a bright-yellow, soft, crystalline powder, sparingly soluble in water, but dissolving with ease in many dilute acids. The most convenient form is a solution of 1 gram in 100 c.c. of 5% acetic acid. This solution is brownish and keeps pretty well, but it is inadvisable to make up a large amount at once.

With this solution a white flocculent precipitate forms at once when added to a liquid containing notable amounts of nitrates or nitric acid; with small amounts some time is required and the solution should be cooled to 0° C. The precipi-

posed, but they have not had much vogue. The latest suggestion promises to be of much use, the test analyses being satisfactory. It depends on the fact that benzidin sulphate, $(C_6H_4)_2(NH_2)_2H_2SO_4$, is insoluble in water and dilute acids, and that benzidin hydrochlorid $(C_6H_4)_2(NH_2)_2(HCl)_2$ can be titrated as if it was hydrochloric acid, by sodium hydroxid or barium hydroxid, using phenolphthalein as an indicator. The precipitating solution is prepared by dissolving about 40 grams of benzidin hydrochlorid in 500 c.c. of water with a few c.c. of hydrochloric acid, and making the solution up to 1000 c.c. It keeps for some time, if kept in the dark. The solution is titrated with sodium hydroxid or barium hydroxid and the amount required for neutralization noted.

A convenient amount of the solution to be analyzed is introduced into a 250 c.c. flask, rendered exactly neutral, made up to about 150 c.c., and heated in the water-bath. Benzidin hydrochlorid solution is added in excess, the amount added being exactly noted. The solution is cooled, filled to the mark, shaken and filtered. An aliquot part is titrated. The difference between the alkali required for this and that required for the same proportion of the benzidin hydrochlorid before precipitation is the equivalent of sulphuric acid precipitated. The following equation shows the type of the reaction:

$$(C_6H_4)_2(NH_2)_2(HCl)_2 + K_2SO_4 = (C_6H_4)_2(NH_2)_2H_2SO_4 + 2KCl$$

257 of benzidin hydrochlorid precipitates 98 of sulphuric acid or the equivalent of any sulphate.

The precipitated benzidin sulphate is white and flocculent.

Detection of Ammonium Compounds.—Trillat and Turchet (*Bull. Soc. Chem., Paris*, 1905, No. 6, p. 304,) describes a simple test which they claim to be more delicate than Nessler's reagent. A few drops of a 10% solution of potassium iodid are added to the solution to be tested (which should be neutral), and then drop by drop with shaking, a solution of sodium hypochlorite. The ordinary commercial solution will answer. In the presence of even very small amounts of ammonium compounds a brownish precipitate of the so-called nitrogen iodid is formed. The substance is probably largely diiodamin NHI_2 . The reagents, especially the potassium iodid, should be added in small amount, otherwise free iodine may be precipitated. T. & T. find that free iodine may be distinguished

from the nitrogen compound by agitation with chloroform which dissolves the former at once, but acts only slowly on the latter. They find, however, that chloroform slowly decomposes the nitrogen compound.

The convenience of the test and the ease with which the reagents can be obtained will give it value in clinical and sanitary chemistry.

Precipitant for Potassium.—Alvarez (C.r. 140 (1905) 1186) finds that the photographic developer, commonly called "eikonogen" (a sodium naphthol sulphonate) forms a sparingly soluble potassium salt. A five per cent. solution of the eikonogen in water is used as a reagent. This solution must be freshly made as it decomposes in a few hours. The precipitate is in colorless plates and is also liable to decomposition.

Test for Cane Sugar in Milk Sugar.—I have found that the reaction with sesame oil and hydrochloric acid is a satisfactory test for sucrose in lactose, being better than carbonization with sulphuric acid. The test is applied by mixing about 1 c.c. each of sesame oil and strong hydrochloric acid, adding about 0.5 gram of the same to be tested, shaking actively for a few moments and then allowing the liquid to stand for thirty minutes. As little as one per cent. of sucrose can be detected, but for such quantity, it may be necessary to allow the liquid to stand for a longer time. Sucrose can be easily detected in milk-products, and the test will be applicable to the detection of the comparatively new "cream-thickener" consisting of calcium oxid and sucrose. I am studying the applicability of the test to other carbohydrate mixtures.

PROPOSED SUBWAY AT PITTSBURGH.

A number of capitalists of Pittsburgh, among whom is F. T. F. Lovejoy, formerly Secretary of the Carnegie Steel Company, have organized the Pittsburgh Subway Company and have asked the councils of that city for a franchise to build a complete system of subway and surface traction lines from the downtown section in Pittsburgh through the East End and Wilksburg. The estimated cost of the subway and traction lines is given as \$30,000,000, and the projectors promise to push work as fast as possible. At present traffic through the Pittsburgh downtown districts to the East End is very much congested and is steadily growing worse, owing to the rapidity with which the outlying districts near Pittsburgh are building up.

—*Iron Age.*

(Stated Meeting, held Thursday, October 11th, 1906.)

Low Pressures : The Death of Matter.

[Translated by Chief Engineer B. F. ISHERWOOD, United States Navy, from the 5th Chapter of "L'Air Liquide," by GEORGES CLAUDE, former pupil of "The School of Physics and Chemistry," Paris.]

If Industrial Science should be able to congratulate itself on the progress now being made by Liquefied Air, so that there could be said of it with satisfaction that it will furnish in the future a lever as potent as was steam or electricity in the last century, then there could be predicted that astonishing surprises will be produced by Low Temperatures in the domain of Pure Science.

And were it not temerity to attack such high subjects in so modest a work as this, the attempt could be made to show from all the apparently disconnected facts now to be passed in review, how great has been the shaking which the seductive ideas accepted up to the present time by modern physicists have received in their firmest seats.

The notion of *cold*, created and put into the world for the purpose of explaining the opposed sensations of our organism, has been entirely superfluous in science for a long period, having been included in the notion of *heat*. A body *colder* than another is a *less hot* body. A body that cools is a body which loses heat. Pause a little on this last image. To say that a body loses heat is to imagine that it holds within itself a certain quantity of caloric, a quantity, evidently, that could not be unlimited. If, then, this body be placed under proper conditions, there could be extracted from it all the caloric it contained, and it would be brought to the extreme limit of cold—to the lowest temperature that could possibly be realized—which temperature is, for that reason, qualified as the *absolute zero*.

This conception was, at first sight, purely intuitive and philo-

sophic. It came in a direct line from the ideas of Stahl concerning phlogiston; and was the first theoretical essay that gave to modern science its first successes.

Certainly, there was not yet any question of appreciating the depth to which it was necessary to descend on the scale of temperatures in order to reach the ultimate limit of the absolute zero; but, already thinkers could perceive in this intrinsic heat of bodies, the cause which animated the world of matter.

In a brilliant article in the *Revue de Paris*, of April 1st, 1903, Mr. L. Houllévigüe has said: "They saw matter formed of "molecules or aggregated molecules isolated from each other "and pursuing each other in incessant movement like the particles of dust vibrating in the sun-beam, and from this eddying mass they saw escaping waves that propagated themselves "in space by means of an infinitely rare medium which was to "the lightest of known bodies, hydrogen, what the density of "hydrogen was to the density of the heaviest metals. Gases, "especially, appeared as microscopic projectiles darting in "every direction, and continually bombarding, without loss of "force, the sides of the vessel that contained them, only to rebound again and recommence their eternal movement. The "heat contained in the gases took from similar impacts a "more precise significance, it showed the present energy of all "these moving corpuscles; if the gas be cooled, the velocity of "the projectiles diminish, their trajectories flatten, then, all the "corpuscles collapse, but still retain eddying movements; this "is liquefaction. Then, in measure as more and more energy "is taken out of them, the vibrating molecules make less and "less extended movements, and the liquid contracts in cooling. "Very soon the increasing nearness of the molecules to each "other enables them to make among themselves new interactions, their relative positions become nearly invariable, and "the liquid solidifies; but the resulting solid is still animated "with life-like shiverings; it could still be cooled down to the "point at which its molecules would repose, inert, one upon the "other; and then the matter would be dead."

Little by little, precise experiments have given to these superb conceptions the physical bases they needed, and the beginning of certainty to what previously were merely presumptions.

Gay-Lussac supplied in evidence a fact of extreme importance.

Under the action of heat all gases dilate and contract in the same manner; whatever may be their nature, they contract when they cool; they contract by the two hundred and seventy-third of their volume at 0 degrees Centigrade for each lowering of one degree Centigrade in their temperature; if, then, the temperature could be lowered to 273° below 0° , the volume of the gases would become nul. Or if, conformably to the ideas that have been previously expressed, if the size of the intermolecular spaces be connected with the quantity of heat in the body, then, if, in the case of gases, these spaces become nul at 273° , the gases would contain no heat, and, consequently, they would be at the absolute zero. The notion then becomes precise.

Nevertheless, it might be rash to draw, without further precautions, so general a deduction from one particular set of facts. But, on all sides, and in quite different fields of investigation, very precise facts do appear which add to the foregoing deductions the important support of their evidence.

One of the most remarkable can here be cited, obtained by the genius of Ampère previous to the announcement of the fact in question.

Pressed by the necessity of combining in the same theory the inseparable phenomena of electricity and of magnetism, the illustrious scientist was led to consider magnetism as due to the circulation of currents of electricity around each molecule of the magnetized body. One difficulty, however, embarrassed him, namely, how to reconcile the expenditure of inherent energy in the circulation of the electrical currents as they are revealed to us, with the maintenance, indefinitely and without expenditure of energy, of the magnetism of the magnets? The adverse argument assuredly required refutation, and an admirable hypothesis enabled it to be made, which later discovered facts confirm in the most remarkable manner. According to this hypothesis, the conducting molecules do not oppose any resistance to the propagation of the current; electrical resistance only appears during the passage of the current across the intermolecular spaces. Now the elementary currents preserving the magnetism of each magnetized molecule,

not having to pass through any intermolecular space, can persist indefinitely without expenditure of energy. In this manner is reconciled with the thesis of the identity of magnetism and of electricity, the disconcerting fact of the permanence of the magnets.

But an hypothesis can only remain in science by the verification of the different consequences predicted by it. Now, from Ampère's hypothesis can be deduced that the electrical resistance of good conducting bodies ought to diminish with their temperature, since when they cool they lessen their intermolecular spaces which the current has to cross. This consequence is perfectly verified by experiment: not only does the resistance of the pure metals diminish when their temperature lowers, but this diminution takes place with such regularity that by prolonging the curves of resistance beyond the experimental limits, the temperature can be found to which it is necessary to descend in order that all resistance completely disappear, which is to say, in order that, according to Ampère, the molecules come into absolute contact with each other.

Now—coincidence very remarkable—the physicists, who, at the suggestion of Maxwell, proceeded to make, for the first time, this extrapolation, found in this manner precisely the limit 273° Centigrade which the gaseous theory assigns for the absolute zero! This was at once, could it be implicitly accepted, a striking justification of the views of Ampère, a confirmation of the theory which assigns to magnetism and to electricity a community of origin, and the definitive establishment of the ideas of the physicists regarding the absolute zero.

Besides, each limit surpassed by the succeeding one in the production of low temperatures, has been the object of verifications that rendered more and more complete the confidence of scientists. At the temperature of liquefied air, about 85° Centigrade above the absolute zero, the diminution in the resistance of pure copper, also the contractions of hydrogen and of helium, furnished precisely the results calculated in advance from the theories of Gay-Lussac and of Ampère: the cohesion of the metals was considerably augmented conformably to the *desiderata* of modern physics, and the fatal stroke was given to the partisans of that old and poetical cosmogonical theory of Laplace, according to which the interattraction of matter re-

laxed at low temperatures in order to permit dead stars to fall to dust and contribute their ashes to the formation of new worlds.

Finally, the most violent reactions at atmospheric temperatures calm down in a progressive cooling to such an extent that at the temperature of liquid air they preserve only a pale reflex of their primitive vivacity, thus putting in striking relief the entrance of matter into that lethargy which is the commencement of its definitive death.

Notwithstanding all this, and the investigations of Dewar, and the magnificent work of the "Royal Institution," a considerable interval is still left in the march towards the absolute zero.

In 1899, after five years of researches and of persevering effort, liquid hydrogen, the substance, according to certain physicists, of which the enormous globe of Saturn is composed, is, for the first time, manipulated by human hands. By means of it, only 21° Centigrade separates us from the absolute zero; that is to say, one-fourth of the interval which still remained with liquid air. Palpitating moment! At this temperature can a decisive experiment be made to establish definitively our science on the most essential foundation? Bitter disillusion! Plunged into the bath of liquid hydrogen protected by triple spaces of vacuum from being heated externally, the experimental copper-wire shows only a reduction in its resistance to the one hundred and fifth of its initial value, an enormous reduction without doubt, but insufficient to enable the curve to touch at the absolute zero, the axis of the abscissas.

This poignant disappointment seems, for the rest, to be only a warning.

While the scientists expected to find at the temperature of liquid hydrogen a complete cessation of all reaction, Dewar and Moissan found there a violent combination of fluorine and hydrogen: while the matter ought to be despoiled of all energy in its progress towards the absolute zero, it appears, on the contrary, capable of acquiring, *en route*, new energies, as witness the phenomena of phosphorescence and of fluorescence, which, very rare at ordinary atmospheric temperature, are the general rule at the temperature of liquid hydrogen.

And more surprising still; not only does the matter not ap-

pear moribund, but life itself seems capable of resisting this extreme cold; witness microbes vigorous after weeks of immersion in liquid hydrogen; witness seeds of cereals which, under the same circumstances, lose nothing of their germinative faculties; tending thus to furnish reason to the defenders of the very original thesis of the community of the origins of life in the universe, since the vital germs would have been able to be transmitted from one planet to another without being destroyed by the enormous cold of the interplanetary spaces.

Are we then definitively to have done with our old theories, so simple and so seductive, and from which so many experimental and philosophical deductions seemed to constitute a harmonious whole? Is it necessary that we resign ourselves to the belief that nothing is simple in nature?

Certainly, at this moment the motives are not lacking to incite to that deceptive belief the scientists whose convictions have thus been weakened. With radium, have they not on other primordial points collided with the inexplicable? With regard to this science of low temperatures itself, have they not seen the complexity, almost the confusion, produced by introducing it into a question which from the origin of chemistry seemed so simple as that of the constitution of the atmosphere?

The atmosphere, in fact, is no longer the invariable mixture of nitrogen and oxygen with which we have been so familiar. After the first shock given to this belief by the discovery of Argon, surprises multiplied in a singular manner when the liquefaction of air and of hydrogen allowed the undertaking of their fractional distillation, the result of which is that ten new elements have been discovered.

Nevertheless, who can say whether we do not alarm ourselves too soon, and whether all this troublesome complexity is not more apparent than real? If radium conceals its mystery too jealously, perhaps we can hope on other points a more simple explanation. If, as many eminent minds believe, the unity of matter will at some future time be demonstrated, it is not the fact of having found in the atmosphere somethings to lengthen the list of our simple bodies that will be a difficulty, since they will act only as added terms of a more or less condensation of the prototype of all matter, of the *pantogen* of

Hinrich and of Schutzenberger, which is, perhaps, after all, only the *ether* of the physicists.

Still better is the chance of finding in the terrestrial atmosphere the *nebulum* that sends its radiations from the distant mass of stars which form the Milky Way; coronium or the gas of the solar crown; *helium*, of which the sun and some stars retain up to the present time a monopoly; the fact of adding all these new proofs to all the previous proofs of parentage established between the earth and the stars by the existence in the latter of iron, of sodium, of hydrogen, and of many other lodgers in our globe; these facts will so much the sooner form a new road towards the demonstration of the original simplicity of things, since they support the great idea of the unity of the constitution of the universe, reinforced, as has been shown, by the possibility of attributing life to a single origin. Finally, as appreciable compensation for that complexity, a little light has been seen at last on the irritating mystery of the boreal auroras, which scientists have despaired of every solving, but whose radiation-enigmas have been identified with the specter of some of the new atmospheric gases.

And now, returning for the last time to low temperatures, the question can be asked, and in an analogous spirit, if there has not been, at least, some exaggeration attached, as appears to have been the case, to the unhopd-for results found for the temperature of liquid hydrogen, to the point of putting in doubt, at a single blow, all our old beliefs?

We very well know now, thanks to the indications of the theory confirmed by the investigations of Dewar, that in measure as the absolute zero is approached, the difficulties of ascertaining the temperature increase with enormous rapidity. In reality, the thermometric scale, graduated according to conditions of a certain order, ought not to be regarded as constituted from one end to the other of degrees of identical importance. It is by *ratios* between the absolute temperatures, much more than by *differences* between them, that the importance of the successive points is measured, so that the degrees as they approach the bottom of the scale acquire, consequently, an extreme importance.

Thus, the difficulties of descending from the ordinary atmospheric temperatures to the $= 190^{\circ}$ Centigrade of liquid air, is,

sc to speak, nothing comparatively with the difficulties of reached the -252° Centigrade of liquid hydrogen, because these $=252^{\circ}$ represent an absolute temperature of $273 - 252 = 21^{\circ}$ Centigrade, *four times less* than the 83° Centigrade absolute of the liquid air. It was thus, too, that Dewar, by means of ebullition in the vacuum of liquid hydrogen, and by its solidification, was easily enabled to reach $=258^{\circ}$ or 15° Centigrade absolute, but he has not been able, notwithstanding that source of refrigeration, to attain in a similar manner the liquefaction of helium though only separated by 8° Centigrade, because, in reality, the 7° Centigrade absolute necessary to be obtained, represents a temperature *twice lower* at least than that of solid hydrogen.

And, when the helium in its turn has capitulated, can we boast of having advanced a single serious step towards the pole of coldness which we flattered ourselves we could conquer? Not at all; because, supposing even that we could succeed at each new point in reducing one half the distance remaining, the absolute zero would still remain the last term of a decreasing geometrical progression, each of the different terms of which would only be accessible to us at the price of the struggle which has continued against helium since 1899.

And before this important capture was made of the last battalions of the thermometric scale, we should, without doubt, conclude that truly we could not really draw such pessimistic deductions from a temperature that we now conceive as still so distant from the purpose of our efforts, and, until we have more ample information, we should preserve intact our present ideas of the nature of the relations between energy and matter.

Here, then, as everywhere else, the object retreats in measure as we advance, and at no point of our science can we flatter ourselves to have touched the origin of things. But our efforts to attain it have not been the less fecund for that reason, and the science of low temperatures has, for its part, well merited of humanity, since this struggle for the absolute zero has, at the same time that it gave unlimited resources to industry, revealed to the mind horizons as extensive.

Development of the Theory for the Kinetic Energy of Gases.

BY GUSTAF M. WESTMAN, New York.

(Concluded from October number, p. 325)

DETERMINATION OF THE HEAT CAPACITY AND TEMPERATURE WHEN VACUUM AND PRESSURE DO NOT CORRESPOND TO EACH OTHER SO THAT THE FORCES ARE ALIKE.

When the vacuum and pressure correspond to each other the heat capacity is 23.

If we make the vacuum half of the size it was when vacuum and pressure corresponded to each other, and the pressure remains, the heat capacity will be altered to 16.2, as we must divide 23 with the square root of the figure, which lowers the vacuum, because both volume and pressure are necessary to constitute a force on which the heat capacity depends, and only one of them is altered.

The product of pressure and vacuum in this case is altered from 220, 364, 458 and 740 to 110, 182, 229, 370, respectively, and the energies from these ranges of pressure are 5080 Cal., 6655 Cal., 7448 Cal., and 9952 Cal., which divided by 16.2 give the reduced temperatures 314°, 410°, 460° and 614°, respectively.

These figures compare very closely with those already found, namely, 320, 413, 466 and 587. Therefore we conclude that the method of determining the heat capacity is correct, and that the lowering of the vacuum has no effect on the temperature.

It must, however, be remembered that the range of pressure cannot go below 91 atmospheres, otherwise the final temperature will not be the boiling point.

On the other hand, when the pressure is increased but the

vacuum remains, the temperature must be multiplied by the figure to which the pressure has been increased, raised to the power of 0.58 (obtained by multiplying 0.29 by 2), because the whole range of pressure is the square of the pressure.

By using these two rules for heat capacity and temperature we can determine those for any combination of vacuum and pressure.

KINETIC ENERGY OF SUPERHEATED STEAM.

Notwithstanding that superheated steam cannot give as perfect results as the air, we will apply the same method used for air, when we will come to some interesting facts.

The heat capacity for superheated steam is 6.5 cal. per molecule, from which is deduced $\frac{k-1}{k} = 0.235$, and the ratio between the two heat capacities $\frac{8.5}{6.5} = 1.307$. The formula for the kinetic energy is $4 \left(n^{\frac{0.235}{2}} - 1 \right)^2 \times c_v \times 273 \text{ Cal.}$

At first we will show that the heat capacity for superheated steam expanding freely, is 24 cal. deduced from $\frac{8.5^2}{3} = 24$, as the square of the heat capacity is divided equally between the three atoms composing the molecule.

When the temperature to be reduced, as, for instance, when air is used as the working substance, goes below 273° , the expansion must take place in a vacuum.

By expanding superheated steam the temperature is reduced to 373° by the reduction of the pressure alone, as indicated by the temperature of saturated steam, which in practice requires but a few degrees to become superheated steam. A special column for the temperature thereof is given for comparison under the heading, Saturated Steam.

For this reason we estimate the reduced temperature by the kinetic index of the pressure alone, multiplied by 373° and divided by 1.307.

It is, however, supposed that the temperature cannot go below the boiling point before all the latent heat is taken away.

We can estimate the relation between pressure and vacuum for steam in the following manner: The molecule of steam

moves in a perfect circle, different from air, which enables us to calculate the vacuum for the kinetic index in a special way.

Just as the area of a sphere divided by 4 gives the area of the circle passing through the center, so does the kinetic index for the range of pressure divided by 4 give the kinetic index for the pressure alone, which, therefore, can be equalized.

The index for the pressure is $4 \left(n \frac{0.235}{2} - 1 \right)^2$ and the index for the range of pressure divided by 4 is $\left(x \frac{0.235}{2} - 1 \right)^2$.

For instance, at 7 atmospheres' pressure the kinetic index is $4 \left(7 \frac{0.235}{2} - 1 \right)^2$, and if this is made equal to $\left(x \frac{0.235}{2} - 1 \right)^2$, x will equal 34 and $v = \frac{34}{7} = 4.86$

In the same way the ranges of pressure and volume are calculated in the following table, which contains the reduced temperatures and a comparison of the temperatures of superheated and saturated steam. For this estimate it is necessary that the molecule shall be a perfect sphere, as in steam, which contains 3 atoms, which is not the case with air, containing 2 atoms:

Pres.	Range of Pres.	Vacuum.	Reduced Temp.	K. Temp.	Temp. of Sat. Steam.
7	34	4.86	$\frac{0.264}{1.307} \times 373$	440°	437°
8	42	5.25	$\frac{0.302}{1.307} \times "$	461°	442°.5
9	51	5.67	$\frac{0.343}{1.307} \times "$	472°	447°.4
10	59	5.9	$\frac{0.388}{1.307} \times "$	482°	451°.9
13.7	97	7.07	$\frac{0.514}{1.307} \times "$	521°	466°
20	178	8.9	$\frac{0.705}{1.307} \times "$	575°	484°

It is easy to confirm the above figures about pressure and vacuum, if the relation between volume and vacuum for steam is considered.

The vacuum for steam is expressed in the following formula,

in which v represents vacuum and v_1 , represents the compressed volume:

$$v \left(1 + \frac{t}{373} \right) = \frac{1}{v_1}.$$

This formula for vacuum of steam corresponds to the formula for vacuum of air as nearly as possible if the difference in temperature between both vacuums is taken into consideration, and the temperature on which the volume depends, in the case of steam, is always above 273° ; while for air it may be either above or below 273° .

We use the figures under heading, "Kinetic Temperature," and divide $\left(1 + \frac{t}{373} \right)$ by p , in order to arrive at the volume v_1 , thus presenting the following table:

p	v_1		$\frac{1}{v_1}$		v		$v \left(1 + \frac{t}{373} \right)$
7	$\frac{1.19}{7} = 0.17$	;	5.88	;	4.85	;	5.78
8	$\frac{1.24}{8} = 0.155$	;	6.45	;	5.25	;	6.51
9	$\frac{1.26}{9} = 0.14$	;	7.1	;	5.67	;	7.14
10	$\frac{1.29}{10} = 0.129$	;	7.75	;	5.9	;	7.61
13.7	$\frac{1.40}{13.7} = 0.102$	;	9.8	;	7.07	;	9.89
20	$\frac{1.54}{20} = 0.077$	;	15	;	8.9	;	13.7

From $\left(1 + \frac{t}{373} \right) = p v_1$ and $v \left(1 + \frac{t}{373} \right) = \frac{1}{v_1}$ it follows that $\left(1 + \frac{t}{373} \right)^2 = \frac{p}{v}$, or that the square root of pressure multiplied by the final temperature is equal to the square root of vacuum multiplied by the initial temperature. This can be seen as follows:

$\sqrt{7} \times 373 = 915$	corresponds to	$\sqrt{4.86} \times 444 = 968$
$\sqrt{8} \times 373 = 1059$	" "	$\sqrt{5.25} \times 461 = 1055$
$\sqrt{9} \times 373 = 1119$	" "	$\sqrt{5.67} \times 491 = 1123$
$\sqrt{10} \times 373 = 1178$	" "	$\sqrt{5.9} \times 482 = 1171$
$\sqrt{13.7} \times 373 = 1370$	" "	$\sqrt{7.07} \times 521 = 1380$
$\sqrt{20} \times 373 = 1669$	" "	$\sqrt{8.9} \times 575 = 1714$

The above calculations can be made directly from the forces

when the molecule moves in a perfect circle, as is the case with steam. When pressure and vacuum correspond to each other, all three forces are alike, and consequently the attractive force is equal to the square root of the centrifugal force.

We measure the pressure in a straight line, notwithstanding its action is along the periphery of a circle, when steam is concerned, and thus the real pressure is 3.14 times greater than the observed.

When the attractive force acts, it induces the centrifugal forces to act, which, therefore, are in proportion to 3.14 p, consequently one of the centrifugal forces must be in proportion to the square root of 3.14 p, which also must be the case with the attractive force, as all are alike.

If the effect is used instead of forces, and as $v = \frac{1}{v_1}$, wherein v_1 indicates the compressed volume effected by the pressure, we can use v instead of pressure and reach the following formula:

$$v = \sqrt{3.14 p}.$$

Applying this formula at 7; 8; 9; 10; 13.7 and 20 atmospheres' pressure, the vacuums will be respectively 4.7; 5; 5.31; 5.67; 6.6, and 7.9 without superheating.

If the steam is superheated, either the pressure or the volume increases in both cases assumed in proportion to the increased temperature divided by 373, which alters the equation to

$$\sqrt{3.14 p \left(1 + \frac{t}{373}\right)} = v.$$
 For respectively 7°, 19°, 24°, 30°, 45°, 91° v is altered to 4.75; 5.12; 5.47; 5.90; 6.98 and 8.82 when found to be 4.86; 5.25; 5.67; 5.90; 7.7 and 8.9.

The energy from the reduced temperature multiplied by 24 compares with the kinetic energy of our formula as follows:

76	×	24	=	1824	Cal.,	when	our	formula	gives	1874	cal.
88	×	24	=	2112	"	"	"	"	"	2188	"
98	×	24	=	2356	"	"	"	"	"	2442	"
109	×	24	=	2616	"	"	"	"	"	2697	"
148	×	24	=	3542	"	"	"	"	"	3628	"
202	×	24	=	4848	"	"	"	"	"	4970	"

DETERMINATION OF THE KINETIC ENERGY BY THE PRODUCT OF THE THREE NATURAL FORCES.

We will now see what the result will be if the forces for steam are separated as formerly by air, and the product of them,

$11^{0.705}$, is multiplied by the unit of energy belonging to the atmospheric pressure, after deducting the energy due to the vacuum.

The greater heat capacity of steam over air, which amounts to $\frac{65}{48} = 1.345$, must, in this case, be observed.

If the product of the forces is used in the calculations, one-third of the excess of heat capacity over the air, or 0.118×546 , must be added to 546, making it 611 cal. as the proper unit of energy for the molecules of steam at one atmospheric pressure.

From this must be deducted that portion of energy which belongs to the rest of vacuum corresponding to the pressure.

For instance, 7 atmospheres' pressure corresponds to 4.86 vacuum, therefore $611 (1 - \frac{100}{486}) = 488$ cal. must be the proper unit of energy. This unit, multiplied by $7^{0.705}$, expresses the kinetic energy.

In the same way the kinetic energy for the different pressures as above, is calculated from the product of the forces multiplied by the proper unit of energy. The results are given in the following table, with a comparison of the three methods used for its determination:

	Product of Forces.	Reactive Forces.	Principal Formula.
$7^{0.705}$	$\times 484 = 1922$ Cal.	1824 Cal.	1874 Cal.
$8^{0.705}$	$\times 496 = 2148$ "	2122 "	2188 "
$9^{0.705}$	$\times 503 = 2392$ "	2356 "	2472 "
$10^{0.705}$	$\times 504 = 2555$ "	2616 "	2697 "
$13^{0.705}$	$\times 521 = 3329$ "	3542 "	3628 "
$20^{0.705}$	$\times 544 = 4500$ "	4848 "	4970 "

The last formula depends on the pressure, to which a proper vacuum must be accessible in order that the forces should be even, which is a necessary condition for it, and is therefore not available under other conditions. Our principal formula for the kinetic energy, however, which depends on the range of pressure, can be used under all circumstances.

To show that the energy of superheated steam expanding against the atmosphere corresponds to our formula, we present the following table, in which the temperature at the beginning

of the expansion is marked $T_1 = (\frac{\text{kinetic index}}{1.307} + 1) 373$, and

the temperature at the end of the expansion is marked $T_2 = T_1$ — the reduced temperature.

As the temperature begins at 373° instead of 273° , corresponding to one atmosphere's pressure, we have here to divide the index by the product of 1.367 and 1.307 = 1.78 in order to obtain the adiabatically reduced temperature.

Pres.	Kin. Index.	$\frac{\text{The same Ind.}}{1.78}$	Reduced Temp.	T_1	T_2
6	0.212	0.119	44.3°	433°	389°
9	0.348	0.196	72°	472°	400°
12	0.456	0.264	95°	503°	408°
16	0.592	0.332	124°	542°	418°

Pressure.	Energy from	Reduced Temp.	Energy from Formula.
6	44.3	$\times 8.5 = 376$ cal.	$0.212 \times 1775 = 370$ cal.
9	72	$\times 8.5 = 612$ "	$0.348 \times \text{"} = 617$ "
12	95	$\times 8.5 = 807$ "	$0.456 \times \text{"} = 809$ "
16	124	$\times 8.5 = 1054$ "	$0.592 \times \text{"} = 1050$ "

$pv^{1.307}$ is about 0.69 during compression, but not constant during expansion.

When our formula is proved to be correct by two such different gases as air and steam, it is reasonable to suppose that this formula will hold good for other gases, even if special rules have to be found governing the temperature and heat capacity.

We will only add that the whole latent and sensible heat is converted into kinetic energy, when the range of pressure is the product of the number of molecules per cubic metre and 22.3.

The great difference between using air instead of steam for motive power is that the temperatures are reduced to 193° below zero by the air, whereas the reduced temperature in the case of steam is 100° above the zero point.

For kinetic energy it is necessary to use matter in gaseous state, and the whole amount of latent heat must be supplied for making steam, out of which only a fraction is recovered as work.

If to this is added that the steam takes 50% more pressure than air for the same quantity of power, the disadvantage of the former system is clearly shown, and can be expressed as follows: As matter is nothing but enclosed energy, and as it is desired to liberate the power to produce kinetic energy, it is better to use gaseous elements and not compounds, in which a part of the energy is already taken away.

As the temperature 193° below zero has been observed by

Prof. G. A. Hirn in his experiments with rarefied air, without any work being performed, there is no question that this temperature will follow when work is done.

By closer examination of the figures for the kinetic energy, it can be found that the energy for air, divided by the square root of the range of pressure, gives a constant figure; namely, 500 cal. per molecule; whereas the energy of superheated steam, divided by the square root of the range of pressure, varies from 320 cal. to 370 cal. per molecule between 34 and 100 atmospheres' range of pressure, but above this is constant 370 cal.

AIR.	SUPERHEATED STEAM.
$\frac{4436}{\sqrt{91}} = 466$	$\frac{1874}{\sqrt{34}} = 321$
$\frac{7360}{\sqrt{220}} = 500$	$\frac{2188}{\sqrt{42}} = 338$
$\frac{9530}{\sqrt{363}} = 500$	$\frac{2442}{\sqrt{51}} = 342$
$\frac{10750}{\sqrt{460}} = 500$	$\frac{2697}{\sqrt{59}} = 351$
$\frac{13570}{\sqrt{740}} = 500$	$\frac{3628}{\sqrt{97}} = 368$
	$\frac{4970}{\sqrt{178}} = 372$

This makes $\frac{500}{370} = 1.26$, or 26% more energy from air than from steam for the same amount of range of pressure.

ACTUAL TEST OF THE FORMULA.

We will illustrate our formula for steam by the experiments made by De Laval Steam Turbine Co. At a pressure of 13.6 atmospheres and a vacuum of $\frac{1}{10}$ atmospheres' pressure, which latter corresponds to 5.9 vacuum, the velocity of the steam was found by several tests to be 4000 feet, or 1220 metres per second.

The energy per kilo of steam is $\frac{1220^2}{19.6}$, divided by the mechanical equivalent of heat, 426. This makes 179.4 cal. per kilo, or 3229 cal. per molecule.

The product of pressure and volume is 80.34, while the formula gives $4 \left(80.34^{\frac{0.235}{2}} - 1 \right)^2 \times 1775 \text{ cal.} = 3195 \text{ cal.}$

VELOCITY OF GASES.

Finally, we will show that the formula for the kinetic energy of gases is in accord with the velocity of the molecules. To this end we must first abandon the generally accepted theory thereof, which says that the gas molecules at ordinary pressure are free to move in rectilinear directions, because they do not exert any mutual effects upon each other, except at extremely small distances.

In opposition to this theory we assume that the molecules move in circles inside the ether at atmospheric pressure, when no difference in pressure exists, but takes a forward motion when the pressure goes from a higher to a lower point. We will show that this forward motion is a circle whose diameter is equal to the square root of the kinetic index multiplied by 2 or 3, according to the number of atoms in the molecules, each atom giving its own impetus to the motion.

This forward motion, however, has nothing to do with the ordinary rotatory motion at one atmosphere, which continues just the same.

On the other hand, the forward velocity shows itself to be in proportion to 3.14 g^2 .

For 91 atmospheres' range of pressure the energy is 4436 cal. per molecule, or 154 cal. per kilo., consequently $154 \times 426 \times 19.6 = v^2$, if v is the velocity and 426 the equivalent of heat in kilogrammeters. This makes $v = 1133$ meters. In the same way the velocities are found for different ranges of pressure. With velocities calculated in this way we compare, in the following table, the velocities or the diameters of the circles in which the molecules move.

Applying this to the air we must add two per cent. on account of the molecules moving in ellipses instead of circles,

which makes the product of 3.14 .96; 2 (+ 2 per cent.) = 308.

WITH VACUUM.

Range of Pres.	Energy per Ko.	Velocity.	Index to K. E.	Diameter.	Diam. x 303
91	154 cal.	1133 meters	3.40	2×1.84	1133 met.
220	254 "	1460 "	5.66	2×2.37	1460 "
363	330 "	1660 "	7.29	2×2.67	1645 "
460	371 "	1760 "	8.2	2×2.86	1762 "
740	470 "	1986 "	10.36	2×3.31	1978 "

WITHOUT VACUUM.

Pressure.	Energy per Ko.	Velocity.	Index of K. E.	2 Diameter.	2d D. x 308
6	16.1 cal.	365	0.347	2×0.591	364
9	21.5 "	471	0.584	2×0.764	471
12	33.5 "	529	0.74	2×0.86	530
16	43.5 "	603	0.96	2×0.94	603

The same calculation for superheated staeam gives the following results:

WITH VACUUM.

Range of Pres.	Energy per Ko.	Velocity.	Index of K.E.	3 Diameter.	3 D x 302
34	104 cal.	932	1.06	3×1.03	931
42	122 "	1010	1.23	3×1.11	1004
51	136 "	1066	1.376	3×1.175	1058
59	150 "	1120	1.52	3×1.235	1116
97	202 "	1300	2.04	3×1.43	1293
178	265 "	1483	2.80	3×1.676	1514

WITHOUT VACUUM.

Pressure.	Energy per Ko.	Velocity.	Index to K.E.	3 Diameter.	3 D x 302.
6	20.6 cal.	416	0.212	3×0.461	417
9	34.5 "	537	0.348	3×0.59	535
12	45 "	613	0.456	3×0.673	612
16	58.3 "	698	0.592	3×0.77	697

If we calculate the diameter for the different volumes, we find that the molecule rotates inside the gas volume.

Notwithstanding that the velocity is derived from the square root of the constant in our formula, multiplied by 2 or 3 times the square root of the kinetic index equal to the diameter of the circle in which the molecule moves, we have executed our examples in order to show that the ordinary rotatory velocity of the molecule goes out of the equation for a change of pressure from a higher to a lower point, and thereby the forward motion is independent of it.

It is easy to see this during compression, because the velocity

stands in direct proportion to the square root of the pressure, which for one atmosphere goes out of the equation. During expansion, however, this must be shown by figures.

To show the ordinary rotatory velocity of the molecule during expansion, we make $4 \left(n^{\frac{k-1}{2k}} - 1 \right)^2 = 1$, whereas this rotatory velocity is calculated by 2×308 , equal to 616 meters for air, and 3×302 equal to 906 meters for steam.

If it is assumed that the height of one homogeneous atmosphere of air at 273° absolute temperature is 8000 meters, and the height of one homogeneous atmosphere of steam at 373° absolute temperature is 17,300 meters, the absolute velocity would be $\sqrt{2g \times 8000} = 395$ meters, and $\sqrt{2g \times 17,300} = 580$ meters in a straight line, which has to be multiplied by 1.57 in order to have the velocity in the periphery, because the velocities are carried over from one molecule to the other, thus making them respectively 620 and 910 meters.

The velocities in all our examples for air and steam, where the expansion is against the atmosphere, do not go as high as this ordinary rotatory motion of the molecule, and consequently this ordinary rotatory motion is not in the equation.

The difference between these two motions is, that the diameter of the forward motion is represented by the actual figures in meters, while the diameter, in the ordinary rotations of the molecules of atmospheric pressure, depends on the actual size of the molecule.

Main results: That the heat capacities of the kinetic energy in vacuum for air and steam are constant $\frac{c_v^2}{2}$ and $\frac{c_v^2}{3}$, respectively, and the work is in proportion to the reduction in temperature, which is in harmony with the potential energy.

That the kinetic energy divided by the square root of the range of pressures is constant; namely, 500 cal. for air, and 370 cal. for superheated steam.

If these figures are multiplied by their respective heat capacities, the products will be equal, $4.8 \times 500 = 6.5 \times 370$. Therefore, and for the reason that $\log. c_v^{\frac{k-1}{k}}$ is constant, we conclude that the kinetic energy is in inverse proportion to the heat capacity. We assume this rule is true for all gases, wherefore

the energy for one molecule, or 22.3 cub. met., of any gas is $\sqrt{n} \times 500 \times \frac{4.8}{c_v}$ cal., wherein n is the range of pressure and c_v the heat capacity for the molecule in question.

That the velocity of the kinetic energy for all gases is in direct proportion to 3.14 g² at all pressures and vacuums.

The kinetic energy of the gas is consequently in proportion to 3.14² × g³, which shows that the acceleration belongs not only to the attractive force, but also to the centrifugal forces.

If to this is added that the unit of energy multiplied by the product of the three natural forces in all instances, no matter what their strength is, conforms with our formula, there cannot be any doubt of its correctness, as most physical formulas rest on units, and numerical figures therefrom are accepted as facts.

The following facts have been demonstrated by our formula, which would not have been the case if the formula was incorrect; namely, for air: That the square of the initial pressure, multiplied by the final temperature, is equal to the square of vacuum multiplied by the initial temperature, and for steam; that the square root of the initial pressure, multiplied by the final temperature, is equal to the square root of the vacuum multiplied by the initial temperature;

That the heat capacity is constant 23 and 24, when pressure and vacuum correspond to each other.

This rule cannot be applied to superheated steam where the range of pressure is less than 100 atmospheres.

By explaining the actual relation between pressure and vacuum, the generally accepted theory that the molecules move in rectilinear courses, is rendered untenable, and the real motion is found to be a rotary one.

As to the kinetic energy of gases, we have to deal with three variables and one constant, which also changes under certain conditions. These variables go from one extremity to the other, and must be determined at the beginning and at the end of expansion. Consequently at least six determinations must be made for every problem.

Through our formula only the product of pressure and vacuum can be determined, and the difference in temperature when the heat capacity is known.

Special rules must, therefore, be found to determine the rela-

tion between pressure and vacuum and the heat capacity, if needed.

When vacuum is used the final temperature is at the boiling point, and in case the expansion is against one atmosphere, the initial temperature can be determined by adiabatic compression.

Convinced that our theory for the kinetic energy of gases is in accord with facts and fully established, we make the following remark:

The formula is deduced from our principal energy-formula, under which law the energies of solid and liquid bodies are governed, consequently the latter, either directly or indirectly, can be considered as the ruling formula to determine the energy at every change of volume for any body.

ERRATA, October number:—In "Development of the Theory for the Kinetic Energy of Gases," by Gustaf M. Westman. Page 317, eleventh line, read "two equal forces," instead of two equal force; page 319, seventh line, read $4 \left(n^{\frac{k-1}{k}} - 1 \right)^2$, instead of $4 \left(n^{\frac{k-1}{2k}} - 1 \right)^2$; same page, thirteenth line, read $4 \left(n^{\frac{k-1}{2k}} - 1 \right)^2$, instead of $4 \left(n^{\frac{k-1}{k}} - 1 \right)^2$; page 320, eighth line, read "in vacuum," instead of is vaccuum; page 321, thirty-third line, read $4 \left(n^{\frac{k-1}{2k}} - 1 \right)^2$, instead of $4 \left(n^{\frac{k-1}{k}} - 1 \right)^2$; page 322, twenty-fifth line, read 493° , instead of 393° ; page 323, twelfth line, read "n is the range of pressure," instead of n is the pressure; same page, thirty-third line, read "logarithmic spiral," instead of logarithmetic spiral.

ZINC INDUSTRY IN UTAH.

The zinc ore product of the Park City district in Utah fell off heavily in 1905 through the caving-in of the Ontario drain tunnel, says Mr. Charles Kirchoff of the United States Geological Survey in a forthcoming report on the production of zinc. A mill equipped with the Blake-Morscher electrostatic separators was put into commission during 1905 at Salt Lake City. At Frisco the Horn Silver Company shipped a considerable tonnage of zinc ore to the Iola works. There has been some talk of building a zinc works at Bonneville, twelve miles north of Ogden.

THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

Announcement has been made of the programme of the fourth congress of the International Association for Testing Materials, which will be held in Brussels, Belgium, September 3-8, 1906. At the general meeting on Monday, September 3, a commemorative speech in honor of the late president, Professor Tetmajer, will be made by Prof. F. Schüle, and there will be a lecture on the industries of Belgium. Section meetings will be held on Tuesday and Wednesday forenoon, with visits in the afternoon to places of technical interest in Brussels and vicinity. There will be a general meeting on Thursday, with reports of sections, and on Friday a visit to the works of the John Cockerill Company, Seraing. The delegates will visit the Harbor Works in Zeebrugge on Saturday. It is stated in the report of the council that the membership on January 1, 1906, was 1814, as against 2200 in the preceding year. The decrease is attributed to the withdrawal of American members, the number from this country having fallen from 600 to 241 in consequence of the action taken at the 1905 meeting of the American Society for Testing Materials in raising its membership fee to \$5 and leaving its members free to take membership in the International Society as individuals. Previously a portion of the \$5 fee of each member of the American Society had been sent to the International Society.

FERROCYANIDE TITRATION.

It is commonly recommended, in titrating ferrocyanide with zinc sulphate, to determine the end point by placing on a piece of iron free filter paper; first a drop of the liquid examined, and then a drop of (acidified) ferric chloride solution. The end point is reached when a blue streak ceases to form after a minute or two at the junction of the two drops. In the *Zeit f. Angew. Chemie*, 1906, p. 615, D. Stavorinus points out that the test may be simplified by using Schleicher & Schüll's filter No. 598, which contains a trace of iron. With this the use of ferric chloride becomes unnecessary, the blue coloration appearing after a minute or two owing to the iron in the paper.

EFFECT OF STRAINS IN COLD-WORKED IRON.

Strains in cold-worked iron or steel may be detrimental. A piece of straight, cold-drawn shafting, if machined, as for instance in key seating or in turning, is very liable to be not straight after the machining, as cutting away a part of the strained metal removes part of the stresses, and those remaining cause the resultant effect to be different from what it was, and the new adjustment necessary is found in a new shape of the piece.

Mechanical and Engineering Section.

(Stated Meeting, held Thursday, October 11th, 1906.)

The Application of Mechanical Refrigeration to Ice Cream Manufacture.*BY JOS. H. HART, PH.D.

The application of mechanical refrigeration to the manufacture of ice cream is one of the developments of the last few years which is destined to become very much more prominent in the near future. The manufacture of ice cream has always been considered rather a small business, requiring small capital, and from its very nature necessarily constrained to exist in rather small units. This is still true in many sections, but changes are rapidly taking place, and there exist at present considerably over a score of large ice cream factories each of whose output requires from 50 to 100 tons of ice daily in its manufacture during the summer months. In some localities, whole states are supplied from a common center, and the number of factories in this class is rapidly increasing. Remarkable as it may appear to the refrigerating engineer, in nearly every case, this ice is purchased in the open market, and antiquated methods of manufacture exist everywhere and nearly every large plant remains practically a collection of small units under a common roof. But a change has commenced, and the reason for this change and the reason that it has not come sooner is easily determined.

To see this clearly, we must understand the old methods of ice cream manufacture, their advantages and disadvantages, and the conditions that must be met in a modern refrigerating plant used for this purpose. The use of cyrohydrates, of which ice and salt is one of a large class, as a method of refrigeration is one of the most wasteful and uneconomic processes known in engineering physics, and is not in the same class with

*Read by title.

a modern ammonia machine. It has been superseded in practically every refrigerating line save that of ice cream production and the reason for this is two-fold. As has been said before, ice cream factories, until recently, have always existed in small units, and the waste, although relatively large, was practically small. Percentage profits were large, but the amount of sales did not warrant a large outlay and the capital and skilled labor required for any other process. In the second place, and this is a difficulty still very prominent, the utilization of any other method of refrigeration for the production of ice cream did not eliminate totally the use of ice and salt, which must still be used for packing and shipping. A number of the large ice cream plants have installed refrigerating machines, the majority to produce their own ice and cold brine entirely, but some few freeze only with machines and buy their ice for packing and shipping.

It is thus seen that a refrigerating plant for ice cream making is an ice making plant primarily, with slight modifications for freezing and storing the cream, but not subject to the limitations enforced in commercial ice manufacture due to the use of distilled water and the construction of the ice in large cakes freed from air. There are other limitations affecting the capacity of the compressor, etc., which can best be understood by a review of the process of manufacture from the taking in of the raw material to the output of the finished product.

The cream, immediately on arrival at factory, is put in cold storage chambers and cooled to about 35° Fahr. and kept at that temperature for several days if necessary. It has been found that a certain amount of ripening of the cream is beneficial both to the taste and consistency of ice cream, and there is a very marked deterioration with use of fresh cream. This ripening can be hastened by the use of lactic ferment and cream ripening machines such as are used in dairies for butter manufacture. These machines, which are made by the Creamery Package Co., are very useful and save considerable time, but are not in general use, except in the larger ice cream factories, most firms buying cream of the required ripeness or allowing it to attain this by standing. When the cream is ready for use it is taken to the mixing room, where the various ingredients are thoroughly mixed, often by hand, and then

taken to the freezer. There are a number of different types of freezers, and recently a number of new continuous freezers have been invented and put on the market, but they are not used to any great extent and have not proved very satisfactory. The ordinary household freezer is well known and is the common type used in large factories with slight modifications. They are generally in 40 quart units and are belt driven, and are cooled by ice and salt or cold brine, which may come from an ice and salt tank or from an ammonia refrigerating system. There has been one quite recent improvement, however, which bids fair to be of permanent value and which is the main feature of the Emory Thompson Brine Freezer. In this freezer, the power is applied continuously and means are devised for emptying and filling the freezer without stopping the machine, and the advantage is so great that it is being installed in all modern plants. It takes from 12 to 15 minutes to freeze a 40-quart batch of cream with the ordinary freezer. Cream swells in the freezing and it is customary to double the output by this process. Thus 17 quarts of the mixture will become 34 quarts of ice cream in the ordinary time of freezing, but it is possible to increase this output to 40 quarts by freezing for about 23 minutes, although the liability of buttering the cream by this process is much increased. The freezer serves a three-fold purpose; it cools and partially solidifies the cream, it thoroughly aerates it and produces the swell, and finally, it thoroughly mixes the cream, smoothing out the lumps and grains and hastening the process of freezing at the same time by bringing new material constantly in contact with the cold walls.

Contrary to general belief, the cream is not frozen in the freezer. Cream begins to thicken from the cold at about 25° Fahr. It has no definite freezing point, but is considered hard at from 6° Fahr. to 8° Fahr. It is put in the freezer and cooled to about 15° Fahr. It can still be poured in large masses at this temperature, but is thick enough to retain air bubbles and to stand without settling for some time. The temperature of the ice and salt rarely falls below 3° Fahr. or 4° Fahr. below zero and is generally variable throughout the mass, so that the use of brine is preferable if for this reason only, as its temperature is nearly uniform. With an ammonia machine for cooling the brine, it is generally carried about 10°

Fahr. below zero, and this permits six or seven batches to be made in an hour, while the ordinary freezer only allows four or five batches at the most in the same time.

The cream is taken from the freezer and carried to a setting tank where it is kept at a temperature of about 10° Fahr. below zero for from two to four hours and frozen solid. If the brine system is used, the brine for the setting tank is carried on the same circuit with the freezers. If ice and salt only is used, it is put in shipping packages and kept sometimes for as much as eight hours, with constant renewals of ice and salt until shipped. The setting tank consists of an insulated brine tank with a framework to hold the cans of ice cream and a special arrangement to prevent the flooding of the cream with brine.

Now, in regard to the quantity of ice and salt used in making ice cream, or the refrigeration necessary for the production of ice cream in bulk. In practice it takes about 150 pounds of ice and about 40 pounds of salt to make one 40-quart batch of cream. Of course, these figures are cut down considerably when cream is made continuously, but a smaller retailer will use 300 pounds of ice a day to make and store 40 quarts of cream and between 800 and 900 pounds to make approximately 100 quarts of cream and keep it. The great cost is the shipping expense, and this depends on the size of shipping packages. Large concerns have been able to get the total ice consumption for manufacture, storage, and packing for shipment, down to between 400 and 500 pounds of ice per 40-quart can of ice cream, the variation being dependent on the average size of shipping packages. The quantity of ice used for manufacture is much smaller when cream is made continuously, so when figures are desired on refrigeration for a plant, it is best to neglect this factor and consider 50 pounds of ice per gallon of ice cream necessary for shipping purposes alone, in plants having an output of not less than 1,000 gallons of ice cream per day.

Now, in regard to the thermal properties of ice cream itself and the amount of refrigeration necessary in its manufacture.

In a 40-quart batch about 16 quarts of cream are taken, four quarts of condensed milk, and sugar and flavoring and some kind of thickener sufficient to make about 22 quarts. This is sufficient to make ten gallons of ice cream. It weighs

between forty-five and fifty pounds. It has a specific heat varying between .70 and .80 B. T. Units. Its latent heat is indefinite as it does not freeze at any fixed temperature, but gets thicker and harder as it gets colder and is practically solid at about 6° Fahr., beginning to solidify at about 25° Fahr. The total heat of cream between 70° Fahr. and 32° Fahr. varies from 25 to 30 B. T. Units, between 32° Fahr. and 6° Fahr. it varies from 85 to 95 B. T. Units per pound of the mixture. The water ices are considerably higher, ranging from 150 to 170 B. T. Units as the total heat from 70° Fahr. to 6° Fahr. per pound, and it is better to take this higher figure in computing refrigerating values. Of this heat, 100 B. T. Units are absorbed in the cooling room to lower to about 35° Fahr., 600 B. T. Units in the freezing process or in the manufacture itself, and 200 B. T. Units in the setting tank per gallon of cream. The two latter figures change somewhat, depending on the manufacture of water ice or ice cream, but the total remains the same. Fifty pounds of ice absorbs 7,100 B. T. Units and it is generally assumed that it takes an absorption of twice this number of B. T. Units to make this much ice, say roughly 14,000 B. T. Units. If we allow 50% loss by radiation in the manufacture of ice cream, due to the low temperature carried and to the fact that insulation is seldom carried on a freezer, we have a total of about 15,000 B. T. Units per gallon of ice cream, of which approximately 10% is used in freezing and storing the cream.

Now, ice is usually made at a brine temperature of from 15° Fahr. to 19° Fahr. This corresponds to an ammonia temperature of zero Fahr. of the suction gas. In order to maintain twenty pounds (Gauge). The capacity of a compressor is generally rated at fifteen pounds suction pressure and a temperature of 0° Fahr. of the suction gas. In order to maintain a brine temperature of 5° Fahr. below zero, the suction gas is kept at a temperature of 17° Fahr. below zero, and this means a suction pressure of less than five pounds. This means that a machine must be cut down to three-quarters of its normal rating and considered at about one-half of its ice making capacity when used for this purpose. Besides, the ratio of useful to total work is much diminished when run at this pressure, and the fuel cost per

ton correspondingly increased, and this in the face of the fact that only about 10% of the refrigeration is required at this temperature and the remainder could be used in a normal ice making plant. This problem has been attacked in a number of ways. Some firms have small refrigerating plants to freeze and set the cream only and buy their ice for shipment. This eliminates the mess and trouble in making the cream, but is not economical unless labor and power are at hand for other purposes and do not enter as large cost factors. The ice and salt must be supplied for shipment and there is not much difference in the total cost and mess and labor with ice and salt whichever method is used. Another method is to have a separate ice making plant and use this ice to make the brine for the freezers and setting tank.

There is no doubt that it pays for even a small ice cream manufacturer to make his own ice. He does not use filters and has no need of distilled water. He can use a gas engine as a source of power and generally has this on hand or needs it to run the freezers and the ice crusher, and needs no more labor to attend to both. He can use the excess labor about the place to draw ice as it is needed, and can have on the same brine system a cold storage room to cool the fresh cream and to store the packed cream before shipment. There is no extra office or management expense and the ice can be made in small blocks very rapidly. An extra brine storage tank could be pressed into service at night and much of the danger of packing and setting at night in the hot summer months could be eliminated, and the plant shut down at night without special preparation.

A number of larger firms use refrigerating machines entirely, for the freezing and setting of the cream, cold storage room, and the making of ice for the packing and shipping, and all this on the same brine circuit in spite of the diminished capacity and increased cost of operation of the plant, consequent to the use of this low temperature. The truth of the matter is that the use of ice and salt is so wasteful and costly, that it is difficult under almost any circumstances, to find anything that can compete with it in this direction. The ice cream manufacturer pays in the open market from one to two dollars a ton for ice delivered, and a number use from sixty to eighty tons a day

in the summer months, and about one-quarter of this weight in salt at a cost of ten to twelve dollars a ton for the salt. In one or two factories, two separate refrigerating systems are used and this of course solves the problem although increasing the cost considerably. The use of a small auxiliary compressor cooling a separate brine system for the freezer and setting tank, and compressing into the suction side of the main ice making compressor has been suggested but never tried, although it could be run with considerable efficiency as the pressures on both sides are low.

We have been speaking hitherto about the wholesale ice cream manufacturers. Now, there are a large number of department stores, restaurants and hotels use from one hundred to two hundred gallons of ice cream every day and make it by the ice and salt method. The shipping cost is not a factor to these men, and there is a distinct advantage in the use of mechanical refrigeration. It takes from one and a half to two tons of ice a day to make and keep one hundred gallons of ice cream by the old method and between four hundred and five hundred pounds of salt. If they have their own refrigerating and ice making plant in the place for other purposes this is not so bad, but a special plant for ice cream will still pay. One ton refrigeration will keep cold about 200 cubic feet of well insulated space, if held at zero Fahr., in rooms of less than 1,000 cubic feet capacity. Accurate figures for setting tanks at 10° Fahr. below zero are not known. A settling tank of about sixty cubic feet is ample room for 150 gallons of cream, and with an unprotected brine freezer, one ton refrigeration seems necessary to keep the system in normal working order. The one hundred gallons of cream take roughly half a ton refrigeration, and this is to be made in the day-time and stored at night, so that this seems to be about the limit of a three-ton compressor. Of course, it may stand an overload, exactly as ordinary systems do, but it is best to figure on a three ton for this service and a five ton for 200 gallon, and this is about the limit required for the amount of cream used under such conditions.

Sections.

(Abstract of Proceedings.)

MINING AND METALLURGICAL SECTION.—*Stated meeting* held Thursday, October 4th, 8 P.M. Mr. James Christie in the chair. Present seven members.

The paper of the evening was presented by Prof. A. E. Outerbridge, Jr., on "Recent Progress in Metallurgy." The speaker reviewed the numerous advances made in various branches of the science, and gave an instructive summary of the remarkable industrial results accomplished during the past year.

The Chairman tendered the thanks of the meeting to the speaker and the session was adjourned.

WM. H. WAHL, *Sec'y pro tem.*

SECTION OF PHYSICS AND CHEMISTRY.—*Stated meeting* held Thursday, October 11th, 8 P.M. Dr. Edward Goldsmith in the chair. Present, nineteen members.

The Chairman introduced Dr George F. Stradling, Prof. of Physics in the N. E. Manual Training School, Philadelphia, who presented a paper on "The N-Rays and Other Allied Rays." The communication was, substantially, a critical review of the extensive literature of the subject. It was freely discussed.

A paper on "Tax-free Alcohol," presented by Mr. Albert P. Sy, and one by Dr. Edward Hart, on "The Application of Refrigeration to Ice Cream Manufacture," were read by title, and referred for publication. Adjourned.

W. J. WILLIAMS, *Secretary pro tem.*

Committee on Science and the Arts.

(Abstract of proceedings of the stated meeting held Wednesday, October 3d, 1906.)

MR. HUGO BILGRAM in the chair.

The following reports were adopted:

(No. 2374.) *Improvements in Analytical Methods and Apparatus.* Dr. G. H. Meeker, Philadelphia.

ABSTRACT: The inventions and improvements in analytical apparatus and methods embrace the following items:

The Micro-burette: This device consists of a small, accurately graduated burette provided with a combined stop-cock and stirring rod, permitting the addition and mixing of very small and measured amounts or reagents to samples of liquids contained in small vessels, such as test-tubes. The improvement affords a convenient means of volumetric testing on a small scale.

Apparatus for Centrifugal Analysis: This apparatus includes a special vernier caliper and an improved quantitative tube, by which means a fine

graduation of the space holding the precipitate is made possible. The tubes graduated by this method have been employed for the determination of chlorides, sulphides, phosphates and dextrose in urine, and the results obtained are reported to be extremely accurate.

Apparatus for the Determination of Urca: This apparatus resembles closely some of the well-known forms of carbon dioxide apparatus by the Fresenius-Will method. The report states that it is very well adapted for its intended purpose.

The Synthescope is a simple contrivance which permits the ready observation of reactions occurring at the contact surface of two liquids, *e. g.* the precipitation of albumen by the action of nitric acid upon urine containing small amounts of this substance. It is a glass tube, the lower end of which is drawn out to a fine point, which is curved so that the liquid discharged from it passes upwards forming a layer above the point of discharge. The apparatus is admitted to give excellent results.

Improvement in the Babcock Milk-fat Test: This consists in the addition of a special mixing chamber for the sample and added acid. The report states that by this addition the manipulation of this method is somewhat simplified.

Balances for Weighing Bulky Objects: The weighing of bulky objects is effected practically in the same way as in balances used for the determination of the densities of gases.

The instrument, intended for very fine or "critical" work, is essentially a small analytical balance embodying some of the features of the assay balance.

In addition to the foregoing, the applicant submitted for investigation certain *Improvements in Analytical Technique:* These include (a) the sampling of urine by means of the centrifuge; (b) the filtration of certain urines; (c) the testing of urine for sugar by means of phenylhydrazine; (d) various improvements in handling Dare's hemoalkalimeter; (e) a simple method of determining slight changes in the color of litmus paper; (f) a ready way of making the iodoform test for acetone in urine; and (g) the volumetric determination of chlorides in urine.

The sub-committee finds that all of these devices and methods exhibited more or less novelty and utility, in recognition of which the Committee awarded the Edward Longstreth Medal of Merit. [Harry F. Keller, Chairman; W. J. Williams, William O. Griggs.]

(No. 2382.) *Etch-Powdering Machine.* Lewis E. Levy, Philadelphia.

ABSTRACT: This invention is covered by letters patent of the United States, No. 800,225, Sept. 2, 1905, granted to applicant, and has for its object the powdering of a metal plate to prepare it for the process of etching. This includes the powdering of the design on the flat surface of the plate before the first etching, and the subsequent powdering of the sides of the lines and stipples of the design after the first etch to protect them from the action of the acid in the next etch. This has heretofore been done by hand, and requires skill, good judgment and considerable labor. A complete description of this machine with illustrations will be found in this *Journal*, Vol. clxi, pp 59-69, to which the reader is referred.

The invention has been reduced to practice, and is now in successful use in several large newspaper establishments.

The Committee's report on the investigation concludes as follows:

"On account of the importance of the rapid reproduction of photographs and sketches for newspaper work, and of the advance which this machine makes in this step of the process, in addition to the admirable design of the machine, we recommend the award of the John Scott Legacy Premium and Medal to Louis Edward Levy for his machine for Powdering Plates for Etching." The report was adopted. (*Sub-Committee*: Wm. H. Thorne, Chairman; M. I. Wilbert.)

The following report passed first reading:

(No. 2379.) *Apparatus and Method for Detecting Electrical Oscillations*: Louis H. Walter, Prof James A. Ewing.

THE SECRETARY.

The Franklin Institute.

(*Proceedings of the statcd meeting held Wednesday, October 17th, 1906.*)

HALL OF THE INSTITUTE,
PHILADELPHIA, OCTOBER 17, 1906.

MR. JAMES CHRISTIE in the chair.

Present, thirty-eight members.

Additions to membership since last report, three.

The first communication of the evening was presented by Mr. J. C. Trautwine, Jr., on the subject of "Legislative Engineering," in which the speaker severely criticised the system prevailing in Philadelphia and elsewhere whereby the local legislative bodies are permitted to interfere in the execution of engineering works. The speaker's remarks were illustrated with the aid of lantern photographs.

Prof Carl Hering followed with a description of the "Decker Primary Battery," and illustrated his remarks by an exhibition of, and demonstration with this apparatus.

On motion, the invention was referred for investigation and report, as to its merits, to the Committee on Science and the Arts.

Prof. A. E. Outerbridge, Jr., made some informal remarks on "Recent Progress in Metallurgy." His remarks were devoted chiefly to an account of the enormous growth in the production and consumption of metals—especially of iron and steel. He devoted some time to the consideration of the subject of special or self-hardening steels, which depend, for their remarkable properties, on the addition of small percentages of the rare metals, such as tungsten. He alluded also to the great advance recently made in foundry practice, whereby the texture, strength and qualities of one and the same cast-iron may be modified at will, and exhibited a remarkable specimen to illustrate his statement.

The Chairman expressed the thanks of the meeting to the speakers of the evening, and the meeting was adjourned.

WM. H. WAHL, *Secretary*.

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FOR THE PROMOTION OF THE MECHANIC ARTS

VOL. CLXII, No. 6 81ST YEAR DECEMBER, 1906

The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

THE FRANKLIN INSTITUTE.

(Stated meeting held Wednesday, October 17th, 1906.)

Legislative Engineering.

BY JOHN C. TRAUTWINE, JR.

By "Legislative engineering," I mean engineering by legislative bodies composed of laymen, as distinguished from engineering by engineers.

Directly or indirectly, all public works are under the charge of the public itself. But there are differences in the degree of directness, in the extent to which control of the works is delegated by the public to specialists, and in the manner in which such delegation is secured.

This delegation of control may come about either by choice or by compulsion.

In despotic countries it is brought about by compulsion. The public is not asked whether or not it will delegate the control of its works to specialists. But, as civilization advances,

and as the magnitude and complexity of public works increase, the people appreciate more and more the advantages and the necessity of delegating the control of the works to those better qualified to conduct them than the public at large can possibly be.

Hence, in civilized countries, the delegation of control comes about by the choice of the people. No one thinks of calling a town meeting to decide upon the location of a fire hydrant. But the question still remains, to whom and to what extent shall the control be delegated?

In Philadelphia, as in most other places, the control of public works was early delegated to a body of laymen, selected to represent the people and in Councils assembled, and the Councils, in turn, appointed officers, supposed to be specially qualified to supervise the works. These officers carried out the instructions of the Councils.

If the Councilmen had had the intelligence to recognize, and the moral strength to avow, their limitations, all might have been well. But, even in their early days, we find the City Councils indulging in the pastime of hampering the experts in charge of the works, either by actual interference or by the simpler and always fashionable method of starvation.

Thus we find Benjamin H. Latrobe, the engineer who built our city's first water works, writing, in November, 1804, to Nicholas I. Roosevelt, who built the pumps in those works:

"First, the subcommittee of the Watering Committee must assent to an arrangement,—then comes the Watering Committee itself—then the Common Council, and the Select Council,—all avaricious, unjust, ignorant and proud."

The hundred years' history of the Philadelphia water works, from their completion in 1801 to the present time, is a striking monument of the folly of permitting the legislative branch to hamper the operations of the executive.

More than twenty years ago, namely, on June 1, 1885, a few men, zealous for the city's interests, and recognizing the hopelessness of the then existing system, succeeded in having passed through the Legislature, and signed by the Governor, the City Charter, known as the Bullitt Bill.

I ask your attention especially to the following provisions of this charter:

"The executive power shall be vested in the mayor and in the departments authorized by this act."

"Water works * * * shall be under the direction, control, and administration of the department of public works."

"Councils shall, by general ordinances, provide for the proper and efficient conduct of the affairs of the city by the mayor and several departments, and the boards thereof, but they shall not pass any ordinances directing or interfering with the exercise of the executive functions of the mayor, departments, boards, or heads, or officers thereof."

Here, in so far as a layman may presume to read and understand a legal document, the city charter not only distinctly forbids direction of, or interference with, the administration, by Councils, but as distinctly lays upon Councils the duty of finding the means for carrying out the plans of the administration for carrying on the city work.

Not only does the law make these provisions, it is to the interest of the city that the law should be enforced.

During Mayor Warwick's administration, and the early months of the next administration, I had the honor of trying to serve the city as the Chief of its Bureau of Water.

I quote as follows from my annual reports of that period:

1895.—"During recent years, the pumping machinery has been driven to its utmost, and it has been impossible to give it the advantage of that systematic and thorough repair which it so urgently needs."

1896.—"While we have thus far escaped the disaster of widespread conflagration, it cannot be long before the restriction of the supply by reason of inadequate mains, must become a serious menace to the thickly settled and poorly supplied business portions of the city.

"The No. 4 Worthington high-duty pump, removed in 1894, from Spring Garden to Belmont, remains without other protection than the rude house of boards placed over it by employees of the Bureau, and, owing to lack of proper boiler facilities, we have been unable to economize in fuel by using the high-duty attachment.

"At Belmont and at Roxborough high service stations, we are dependent upon one pump, any accident to which would

throw the station out of service, and deprive the district of water."

1897.—"The water service of this city is in a critical condition.

"Between continued starvation, on the one hand, and enormously increasing waste on the other, it is made to appear, as stated in your report of 7th October last, that we are compelled to negotiate with corporations and individuals to secure, for the citizens of Philadelphia, a pure and abundant supply of water.



Fig. 1—Temporary frame shed, protecting high-duty pumping engine at Belmont, 1895 to 1899
Appropriation for proper protection refused.

"As a matter of fact, the city holds in her own hands the key to the solution of her water problem.

"The consumption has again overtaken our pumping capacity; and there will, almost certainly, be a shortage of water at many points during the coming year."

1898.—"The large high-duty pumping engine at Belmont station still remains protected only by a rude frame house erected over it by employees of the Bureau in 1895, our appeals, (repeated in 1895, 1896, 1897 and 1898), for the few

thousand dollars required for its proper protection, having been refused.

"In each of my four annual estimates, I have asked for \$35,000 for the construction of proper coaling facilities for the Queen Lane pumping station. The appropriation having been annually refused, we are compelled to haul the coal through the park in carts, at an annual additional expense of about \$9,000."

At the time, the slender engineering force prepared detailed plans for the needed coaling facilities.

In the face of these quotations, it will hardly be claimed that the legislative branch was not advised as to the conditions and needs of the works.

The following statement shows (1st) these needs, and (2nd) the extent of the appropriations granted by the legislative branch, in response to the representations of the executive:

ESTIMATES AND APPROPRIATIONS.

For Extensions.

	Estimates.	Appropriations.
For 1896.....	\$2,484,150	\$0
" 1897.....	3,339,450	0
" 1898.....	3,735,050	0

It will be noticed that, naturally enough, the estimates for extensions and improvements increased from year to year, as the demand for water increased, and as all appropriations for meeting this demand were withheld.

You will recollect that their honorable bodies were strongly minded to pass an ordinance appropriating \$50,000,000 or thereabouts to the Schuylkill Valley Water Company, in consideration of a "snake" which that Company proposed furnishing to the city, and that the scheme was frustrated only by the timely or untimely exposure of extensive bribery operations, which had resulted in the purchase of many of the city's representatives.

I had devoted all the time at my command to exposing the worthlessness of the Schuylkill Valley Water Company's scheme, but these considerations seemed to have not the slightest weight with the City Councils.

In 1898, \$500,000 were appropriated "for the purpose of constructing a reservoir, furnishing pumping machinery and

mains for that portion of the city lying west of the Schuylkill River;" notwithstanding that it had been shown that the existing pumping machinery was unable to keep even the small old reservoir full of water, and that it had been found necessary to cut off that reservoir from the distribution in order to keep in it any water at all.

An appropriation of \$25,000 was made also for the purpose of cleaning the reservoir, notwithstanding that it had been pointed out that the accumulation of sediment in the reservoir

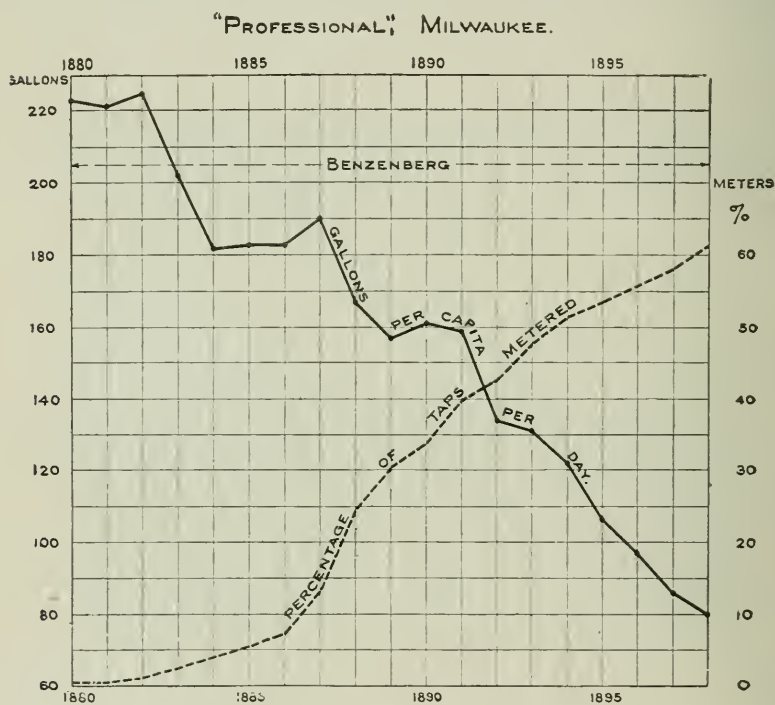


Fig. 2

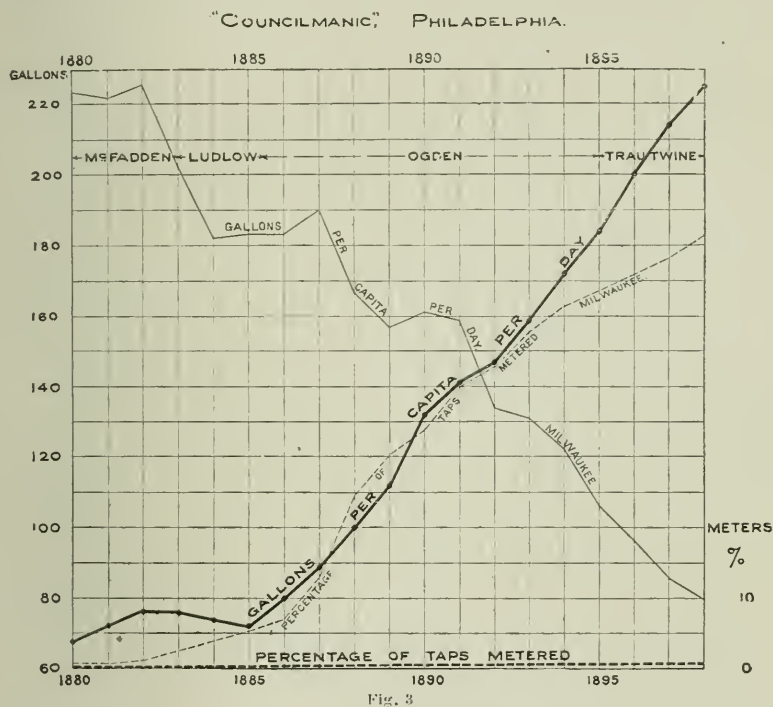
showed that the water was *depositing* it there, and *not taking it up*, and that, if the reservoirs were cleaned to-day, they would have in them, to-morrow, a deposit of exactly the same material.

The contrast between legislative and professional engineering is well shown in the comparison between the experiences of Milwaukee and Philadelphia.

In Milwaukee, from 1880 to 1898, under the strong manage-

ment of Mr. George H. Benzenberg, the percentage of taps metered was increased from practically nothing to 61 per cent., the daily per capita consumption falling, in the meantime, from 220 to 80 gallons.

In Philadelphia, during the same years, and under the legislative system, the percentage of taps metered remained practically at zero, and the daily per capita consumption increased from 68 to 225 gallons.



The next two figures, representing Milwaukee and Philadelphia respectively, show the contrast still more forcibly.

Here the percentage of taps metered are plotted as abscissas instead of the years, as in the figures above.

It will probably be objected to these figures of consumption, as applied to Philadelphia, that they are exaggerated. Every little while, someone discovers that the pumps in Philadelphia are not raising all the water which is claimed for them, and the Bureau of Water is held up to public scorn for "falsifying its

reports." Whereas everybody knows, and the Bureau is constantly insisting, that the figures are known to be exaggerated, and that this is because of the lack of proper facilities for measuring correctly the quantities raised by the pumps.

Naturally, I have drawn largely upon my own experience in the foregoing recital, but it is not to be supposed that my complaint is a personal one, or that I alone have been the sufferer.

During the years 1880 to 1898, three others besides myself had charge (more or less nearly nominal) of the water works,

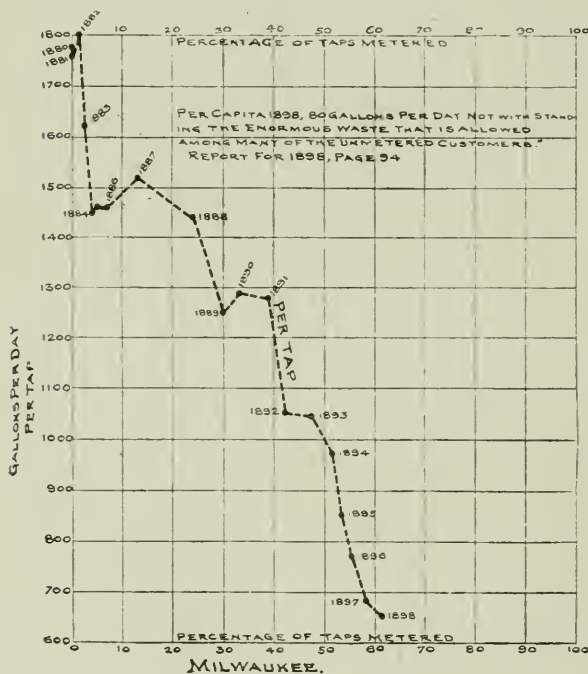


Fig. 4

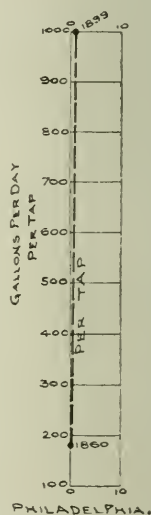


Fig. 5

and since my administration, both Mr. Hand, in the Bureau of Water, and Major Gillette, in the Bureau of Filtration, have had experience of the pernicious activity of the City Councils in meddling with the public works.

In transmitting to Councils his report for 1885 Colonel William Ludlow, Chief Engineer of the Philadelphia Water Works, said:

"I regret that the termination of my official connection with

city affairs and present departure for another field of duty, leave me without adequate time or opportunity to enhance the possible usefulness of this report by formulating therein certain detailed statements and discussions relating to the water service of the city, additional to those which have heretofore been presented; but the apprehension of a duty in this respect partially unfulfilled is tempered by the consideration that my reports for the years 1883 and 1884 contain a large body of important data and recommendations, of which the greater part still remain unacted upon, and that if the conduct of affairs in the future shall proceed with the deliberateness which has marked the securing of urgently needed improvements in the past, so protracted a period will be required for their practical execution as to render superfluous any material additions thereto at the present time."

Upon the assumption of office by the late Mayor Ashbridge, the city purse-strings, for reasons best known to the city fathers themselves, were suddenly and freely loosed; and, in his first annual report, that dated January 20, 1900, we find Chief Hand saying:

"The appropriations granted during the past year provide adequate means to avert serious disaster, and to remove some of the critical features of the works, which for several years, have been sources of great anxiety. This condition is very gratifying, especially when it is remembered that, for the last three summers, it has been difficult, owing to insufficient appropriations for needed extensions, etc., to prevent absolute water famine in some districts."

So striking was the contrast between the new conditions and the old, that Chief Hand found deep cause for thankfulness in the ability "to avert serious disaster, and to remove some of the critical features of the works."

But any city, following the antiquated practices adopted for Philadelphia by their Honorable Bodies, will find its facilities constantly overtaken by the growing consumption; and the lavishness, which enabled Chief Hand "to avert serious disaster" in 1899, seems to have waned very shortly thereafter, as witness the following quotation from his reports, for 1903 and 1904:

1903.—"Urgent recommendations were made for appro-

priations with which to purchase new engines, boilers, and other appurtenances necessary to furnish a sufficient supply of water during the heated term and during extremely cold weather, but, I regret to say, that no provision has yet been made for these important purposes.

"No appropriations whatever were made for extensions during 1902 nor 1903, and no such provision has since been made for 1904.

"The delay in making important additions to the pumpage systems, necessitated, from time to time, by the growth of the city, and the proportionate increased requirements of its water supply, can only lead to additional crippling of the service by overworking the machinery.

"The water supply has been maintained throughout the city as effectively as the water facilities at my command would permit."

1904.—"The above predictions of 1903 have been abundantly verified by numerous and serious breakdowns of the pumps and engines at all our large stations, crippling the service to such an extent that in some instances weeks, and even months, were required to make the repairs.

"Extensive repairs are needed to all the machinery at this station (Queen Lane), but it is impossible to make them, owing to inability to shut down for a sufficient length of time, to prosecute the work thereon.

"This bureau has been very much hampered by lack of funds with which to purchase and lay service mains in all parts of the city."

Yet, upon the occasion of a recent Councilmanic visit of inspection, these gentlemen expressed themselves as aggrieved because they had not been kept informed as to the conditions and needs of the works.

In March last, Major Gillette informed Councils that the immediate placing of a water meter on every tap in the city, at a total cost of about \$5,000,000, would save to our people about \$10,000,000, namely: \$4,000,000 in cost of completing the works, and \$6,000,000 in capitalized cost of pumping, besides hastening the day of filtered water.

Whereupon their Honorable Bodies resolved, with practical unanimity,

"That we unqualifiedly enter our protest against the use or installation of water meters in connection with the water supply of the city.

"That we stand ready and willing to vote all the funds necessary for the perfection of our water supply and the completion of the entire system of filtration, but not for one dollar toward the purchase or installation of water meters in connection with that system."

Their motto evidently was:—"Millions for tribute—but not one cent for defense."

These utterances brought forth the following editorial comment from *Engineering News*, the foremost engineering periodical of the country:

"The resolutions afford so striking an example of popular prejudice and ignorance that they are well worth putting on record for the benefit of engineers and city officials elsewhere."

In a recent interview, solicited by a reporter of the *Public Ledger*, I gave expression to my views on this subject, and I regretted to find my remarks prefaced by the headlines: "Blames Councils for Poor Water Supply."

In his domestic and business capacity, the average Councilman is a harmless and necessary creature. So, Shakespeare informs us, is the domestic cat, yet we do not upon that account place the cat in charge of the canary bird.

It must not be supposed that the writer is engaged in a tirade against municipal legislators in general, or against those of Philadelphia in particular. City Councils are generally large and mixed bodies, composed almost or quite exclusively of laymen. Some of these laymen, in Philadelphia at least, are men who would do honor to any legislative assembly, men with sufficient intelligence to recognize their limitations, and sufficient moral strength to avow them; men who realize that professional questions should be referred to professional men, and who would secure such reference if they could. But the rank and file are made up largely of young men without visible means of support other than their Councilmanic seats, which have been given them by the "leaders" as compensation for services performed or expected, or both, and who themselves in time develop into professional politicians and "leaders." Politicianism is their business, and upon what can be made out

of it they depend for their livelihood. In most cases the dear people (by order of the "leaders," of course,) have repeatedly and enthusiastically returned these gentlemen to their seats by overwhelming majorities, no matter how notorious has been their disregard of the public welfare. Who, then, can blame them if they industriously ply that vocation to which the sovereign people have called them?

The writer asks merely whether it is well that these bodies, in defiance of the City Charter, should be intrusted, by the people, with the control of public works; and the City Councils of Philadelphia have done service to the cause of good government by demonstrating, in the examples before us, that it is not.

In this connection, I quote as follows from remarks by Mr. Edwin F. Smith, Chief Engineer of the Schuylkill Navigation Co., published in 1899:

"Here we have a governing body of nearly two hundred men, 'butchers and bakers and candlestick makers,' professional politicians, few of whom have not an axe to grind, caring little whether they serve the interests of this great city or not, so long as their bread is buttered on the right side.

"The remedy is to take this water question out of Councils. If it was ever intended under the Bullitt Bill that Councils should constitute themselves a Board of Engineers, and devise plans, legislate in the interest of schemers, and even do the detail office work of the Department of Public Works, it is a great mistake that it should be so, and the sooner it is changed the better for those who are still left among the living. I do not believe that it was the intention of the author of the Bullitt Bill that it should be so. If it was, why do not Councils plan the Delaware avenue improvements, the Reading subway, and other municipal work? Well, plainly it is either because there is no money in it for them, or because they are only experts in water works construction.

"When the Bureau of Water is given the same power and working force as the Bureau of Surveys, and when Councils keeps hands off everything except granting appropriations and legislating for the public safety, we will have relief from bad water."

Please bear in mind that these remarks come from an intelli-

gent and educated engineer of long experience and sound judgment, a man eminent for his conservatism, and in no way connected with the Bureau of Water.

THE PRODUCTION OF MICA IN 1905.

The production of mica in 1905 made an important advance over 1904, according to the annual report of the United States Geological Survey, which has been compiled by George O. Smith. Production was limited to six States—North Carolina, Colorado, New Hampshire, Georgia, South Dakota and New Mexico, the order named indicating their relative rank. The total output of sheet mica for these States, as reported to the Survey, was 851,000 lbs., with a total value of \$185,900. Of this quantity North Carolina is credited with 669,000 lbs., valued at \$85,000. The increase in production over the previous year was largely in other States, while the larger increase in value may be accounted for in part by high prices reported by producers in those States. A decrease in the average price for the North Carolina product is due to the increasing proportion of small mica produced for electrical uses. The total production of scrap mica in the United States in 1905 was 856 net tons, valued at \$15,255, an increase in value over the production for 1904. North Carolina's output of scrap mica for 1905 was 175 tons, valued at \$2,375. The separation of the production figures for scrap mica and for the smaller sizes of sheet mica becomes more difficult as the use of these small sizes increases.

The production of sheet mica in 1904 was 668,358 lbs., valued at \$109,462, and of scrap mica 1069 net tons, valued at \$10,854. Thus the value of the aggregated product of mica in 1905 was \$201,155, as compared with \$120,316 in 1904.

The value of imported mica now used in the United States is twice that of the domestic article. In 1905 1,506,382 lbs. of the unmanufactured mica, valued at \$352,475, and 88,188 lbs. of cut or trimmed mica, valued at \$51,281, were imported, making a total of 1,594,570 lbs., valued at \$403,756.

The three principal uses of mica are for electrical insulation, glazing and decoration. The first-named application probably leads in present importance, but the other two uses date back to ancient times, mica antedating glass and also being early used to secure decorative effects.

The increasing use of mica in electrical manufacture has largely modified the demand made upon the mining industry. Small sizes of sheet mica can now be utilized in the manufacture of insulators in lamp sockets, lightning arresters, switch boxes and fuse blocks. More important even is the extensive use that is made of composite mica, micanite, molded mica and other varieties of built-up mica sheets. In the manufacture of material of this class thin laminæ of irregular form and different sizes are arranged and cemented together to form thick sheets of any desired size.

The use of mica for stove windows formerly constituted the principal demand for sheet mica, but this has decreased somewhat in recent years.

The increased use of sheet mica in incandescent gas lamps and for miners' lamps has kept up the demand for glazing grades, so that whatever comes into the market is readily bought. Sheet mica is also used to some extent for phonograph diaphragms and in various small boxes and other novelties.

Scrap mica is utilized in the manufacture of a superior quality of boiler lagging, a mat of finely-divided mica flakes furnishing a fireproof covering that has sufficient strength to be durable, not disintegrating like some other materials, and excelling asbestos and magnesia compound as a nonconductor of heat. The superiority of the mica lagging appears to depend not only upon the low conductivity of the material itself, but especially upon the loose texture of the mica mat.

Ground mica is used in somewhat increased quantities, the coarser grades in mica bronzes and paints and also as an absorbent for explosives. Ground mica also forms an ingredient in some heavy lubricants. The finest ground mica or mica flour finds a considerable market with the manufacturers of high-grade wall papers, the luster obtained by the use of the muscovite dust having the advantage of both permanency and brilliancy.—W. L. C. in *Iron Age*.

PRACTICAL HINTS TO QUARRYMEN.

The only slate region which has been geologically mapped is the western Vermont and eastern New York slate belt. Maps of quarries in this region are included in Bulletin No 275 of the United States Geological Survey, which is a recent report by Mr. T. Nelson Dale on the slate deposits and slate industry of the United States.

These quarry maps are designed to be of practical utility. The coloring shows where the Cambrian green and purple and the Ordovician red slates may be looked for or not looked for. The course of bedding and cleavage has been shown at several quarries by special symbols. The scale of the maps is sufficiently large to admit the entry of many more quarries and symbols. By using a small geological compass to determine the strike of any bed of good slate at any of the located quarries, and transferring it to the quarry maps by means of a protractor, the probable direction of the recurrence of the bed can be ascertained, and so with joints, hogbacks, or dikes. Such a compass should be provided with sights, spirit levels, and movable ring to set off magnetic variation, and have a clinometer attachment to indicate angle or dip.

Quarrymen are very skilled in detecting the presence of good slate from the peculiar appearance of the weathered edge surface. That skill appears to have been their only guide in prospecting in this region. Mr. Dale suggests that it would be well if it were re-enforced by the use of a certain method in exploration, which he outlines.

This bulletin, which should be of practical value to every quarryman in the country, is published for general distribution. It may be obtained, free of charge, by anyone who makes application for it.

(*Stated Meeting, held Wednesday, November 21, 1906.*)

The Survival of the Shortest and of the Easiest in Language.

BY EDWIN SWIFT BALCH.

While it seems hardly within the province of the journals of the applied sciences and of commerce to discuss questions of philology, yet it might be wise for them to consider the recent action of the Simplified Spelling Board recommending a general adoption of three hundred somewhat shortened words, and also the fact that these words are to be used henceforth in some at least of the Government documents. The recommendation of the Board and the Government order amount merely to codifying or recognizing by statute certain changes which natural causes thru evolution have already brought about in the American language, and the questions to be discussed would seem to be: Should or should not the trade journals follow the recommendations which have already been made and which may be made in the future by the Simplified Spelling Board? Will the adoption of these recommendations be a commercial benefit?

The conservative view, which appears to be held by most Englishmen and also by many Americans is that—while admitting that for the expression of thought written English is an uncouth instrument which does not tally with spoken English—we should go on misspelling till the Crack of Doom because our forefathers did so. This theory is not only opposed to all the dictates of common sense, but it is opposed to the law of evolution. Everything everywhere is in evolution: the stars, the earth, humans, animals, sciences, arts: "*Tout lasse, tout casse, tout passe.*" We no longer make darkness visible with rushlights, nor travel about in ox-carts, nor cross the ocean in a "Susan

Constant" or a "Discovery," but conservative people cling lovingly to a superannuated, antiquated spelling.

Language is no exception to the universal change; it is in constant evolution. Local languages, dialects tend to disappear and to be superseded by some more widespread tongue. The writer himself has been able to observe during his lifetime the retrogression of Norman and Breton *patois* before French and the increasing purity of the German spoken among the German peasants. Before the end of the twentieth century, probably only some fifteen or twenty great national languages will remain, where formerly almost every district had its own special mode of speech.

The greater languages themselves are also constantly receiving accretions of newly formed words, many of which have become or are rapidly becoming internationalized. These are principally words of travel, of commerce, or sport; such as hotel, telephone, sleeping car, photograph, beeksteak, restaurant, automobile. Many continental Europeans also often know imperfectly three or four languages and they frequently converse with foreigners in a sort of polyglot jargon. There is thus an evident tendency on the continent of Europe towards the eventual breaking down of the purity of the present languages into a curious conglomerate of them all. In other words, evolution is at work among the more widespread as well as among the local forms of speech, and if there is ever an universal language it will doubtless be the result of this evolution.

A purely ideal plan for improving languages would be to have a Commission or Board constituted of one or more philologists as representatives from each of the great nations. This Board could first agree on a common alphabet for all the great languages and then internationalize all new words concerning inventions and commerce, such as telegraph, invoice, etc. Commerce would certainly be much facilitated by some such arrangement, altho, owing to national prejudice, the chance of anything of the kind being done is about as remote from us, as was Emeric Crucé's dream in 1622 distant from its realization in the Arbitration Tribunal at The Hague in 1898.

In North America also language is evolving: American is evolving away from its parent English. Americans use many

terms differently from Englishmen and moreover they pronounce and accent them differently. In writing and printing the tendency in America is to shorten words and to spell them in the simplest way, so that the Survival of the Shortest seems to be the keynote to the evolution of language in America.

If the spelling of words is shortened, it will mean a saving of time, labor, space and expense in writing and printing. If the spelling of words is made more fonetik, there will be a saving of time, trouble, and mental suffering to school children in their studies, and it will also be much easier for foreigners to learn to read and speak our language. This facilitating the learning of the language would of course increase its employment and its spread, so much so in fact, that a fairly fonetik spelling might in time make American the universal language of commerce.

If our written and our spoken language are ever made to correspond, it will do away largely with the many vagaries of pronunciation now in use. We should no longer hear Eye-talians for Italians, tomehtoes for tomatoes, profeyele for profile and a thousand other such mispronunciations, which are the logical outcome of a mode of speech where the vowel a is miscalled eh, and the vowel i is miscalled eye.

In the case of adopted foreign words, if an accent were placed on the syllable to be emphasized, it would help to clarify our muddled pronunciation. Foreign words are often mispronounced, because the accent is misplaced. We say Sehéra, Himeléyas, Tokío, for instance, whilst those names should be pronounced Sáhara, Himálaya, Tókio. An accent would give a speaker some idea where to throw the emphasis.

The Germans, in many ways a better led nation than the English or the Americans, have two great commercial advantages; the metric system and a practically fonetik spelling. It saves probably a year's work to German children not having to memorize misspelt words and a ridiculous list of unintelligible weights and measures. The growing trade of the Germans shows their wisdom. And with their lines of steamers, their colonizing, their emigration, it is more than probable that the German language will supersede the English language in many parts of the world. This seems likely to be the case in South South America, and we shall have to thank partly our conserv-

atism, self-satisfied with an imperfect language and no system of weights and measures, if we let slip from us into German hands the commerce and the dollars of South America.

English has certainly had the chance of becoming the language of commerce. It is the language of North America, of South Africa, of Australia, of numberless small British Colonies, and it is understood in almost all sea ports. But the insuperable difficulty of the written English language giving so small a cue to the pronunciation militates to such an extent against it that it may be superseded commercially by some other tongue. It may finally prove that the newly invented Esperanto may offer the least resistance for the needs of commerce, but it is certain that the law of Evolution and Survival of the Easiest will eventually solve the problem.

It seems a pity for the English and American nations to block, thru sheer conservatism and inertia, any remaining chances our mother tongue has still of becoming the language of commerce and possibly the basis of an universal language in the future. And it would seem to be the part of wisdom for the trade journals to take spelling reform in hand and hasten the evolution of English into a more serviceable tool and a more easily learned method of conveying thought.

USE OF CALCIUM IN METAL REFINING.

In former experiments made with a view to refine copper, bronze, steel, pig iron, etc., by the aid of metallic calcium, the results were unsuccessful because the calcium was volatilized immediately after being placed in the metal, or burnt on the surface. The process recently invented by Brandenburg and Weins employs the calcium in form of turnings, instead of large lumps, and mixing with turnings or small fragments of one or more metals. This mixture of various metals in a solid form, e. g., brick, is placed in the liquid metal. To refine the latter at a high temperature, the calcium turnings are mixed with those of metals more difficult to fuse than calcium. Thus copper or copper alloy can be refined by mixing calcium, copper and bronze turnings, and molten iron or steel with calcium, iron and steel turnings. Metals can also be refined at temperature of fusion of calcium or lower, the calcium turnings being mixed with those of a more fusible metal, and the cakes or bricks formed from the mixture made to react. Cast-iron, already rather pasty, can be refined by employing, for example, calcium and aluminum turnings. The process was described in *Revue des Produits Chimiques*, Aug. 1, 1906.

IN MEMORIAM.

ROBERT COLEMAN HALL BROCK

was born in Philadelphia July 26, 1861, and was the fifth son of the marriage of John Penn Brock to Julia Watts Hall.



His grandfather's grandfather, John Brock, arrived in Philadelphia on May 3, 1682, on the ship "Friends' Adventure" (five months before the arrival of Wm. Penn on the "Welcome"), having before his departure from Chester, England, received from the Proprietary a grant of land situated on the Delaware River below Morristown, Penna. The original immigrant's grandson (and the grandfather of the subject of this sketch), who was born January 24th, 1792, served in the U. S. Army during the War of 1812, and

later became one of the largest merchants of this city. He was one of the earliest purchasers of anthracite coal-lands in Schuylkill County in this State, and founded the town of Ashland.

Through his mother's family he is related to the Halls of Harford County, Md., and the Watts and Colemans, of Pennsylvania.

He began his education at Dr. Faires' school in Philadelphia, and continued it at St. Paul's, Concord, N. H., under the Rev Dr. Henry A. Coit.

Subsequently he entered Worcester College, Oxford University, England, whence he was called home before, receiving his degree, by the fatal illness of his father, who died shortly afterwards.

He entered the law office of the Hon. George M. Dallas and was admitted to the bar in 1884. In this year also he married Alice the daughter of the late Henry C. Gibson, by whom he has had three children, two of whom and his widow survive him.

In 1888 he entered the firm of W. H. Newbold Son & Co., but retired in 1894 and traveled in Europe to restore his health which had become impaired.

He was already a member of the Historical Society (which he joined in 1883), the Franklin Institute (in 1889), the Rittenhouse Club (in 1890), and the Philatelic Society (of which he was President from 1886 to 1889, and which ceased to exist in 1890), before his journey to Europe in 1894.

Possessed of an alert and well-trained mind and a restless energy, on his return he threw himself with enthusiasm into the ranks of the active workers in additional fields of science, art, and humanity; for among other striking characteristics of Col. Brock was his benevolence, which made him ever ready by counsel, personal effort, and liberal pecuniary contributions, to alleviate want and suffering.

He joined the University Club in 1897; the Philadelphia Club in 1898; the Union League Oct. 18, 1905; the American Philosophical Society in 1899; the Archaeological Society of Penna. in 1901, serving as its President from 1903 to 1905 and as Vice-President till his death. In 1901 also he was elected a member of the Board of Managers of the Franklin Institute, which position also he held till his death, aiding by his excellent advice and generous aid in all its undertakings. We his colleagues know how quick and accurate were his conclusions on matters requiring care and judgment, and how ready he was to give financial help when it was needed.

He was made a member of the Philobiblon Society in 1903. He became a stockholder of the Academy of the Fine Arts, Sept. 1, 1901, and a Director in 1904, in which year also he was elected the Colonel of the 2d Regiment, N. G. P., holding these offices till his death.

In addition to the occupations which membership in the above organizations entailed, he was a Director of the Epileptic Hospital, in Oakbourne, West Chester, Penna.; a member of the Numismatic Society, (Feb. 2, 1882); of the Sons of the

Revolution (May 4, 1901,) and of the Art Club of New York till his death.

But all his energy was not consumed in serious responsibilities. His cheerful nature delighted in sports, and in the society of his fellows. He was an active member of the New York Yacht Club, and of the Corinthian Yacht Club of Philadelphia, and not only heartily enjoyed a yachtman's life but made himself master of the details of managing craft of all kinds.

He was also an enthusiastic automobilist from the date of the introduction of this machine; making many interesting tours and planning others more extensive, not all of which however he was able to carry out.

But the mere statement that he was active in all these associations does not indicate the energy with which he worked for them, the intelligence with which he guided their various policies (or assisted in doing so), and the liberality with which he supported them.

At the meetings, rarely missed, of the managing bodies to which he belonged, he was not content merely to vote "aye" or "no." He weighed every proposition and usually made excellent suggestions of modification or amendment. When the course of action was once decided upon, whether with or without the changes he himself had thought advisable, he was always ready to undertake his share (and generally accomplished more) of the drudgery of visits, collections, searches and all that the perfunctory member avoids and shirks.

Col. Brock's courtesy and gentleness of manner were as remarkable as his extreme modesty and kindness of heart.

He was frank and fearless, yet withal discreet and considerate. He was impatient of ambiguity and indirection, and nevertheless never harsh in judging those whose ethical standard was lower than his own.

He embodied the best type of useful citizen, one whose brains and hands were always at the service of his fellows for worthy objects; and of the American gentleman, exemplifying in his own conduct how a large fortune could be worthily enjoyed and at the same time used for noble purposes.

PERSIFOR FRAZER,

LOUIS E. LEVY.

ALEXANDER KRUMBHAAR.

VARIABLE SPEED TURBINE ENGINE.

A turbine has been patented in England which, by means of two sets of steam admission ports, into either of which steam may be admitted at will, it is claimed will give two different speeds of operation at the same efficiency. For the higher speed the steam is conducted from one set of ports through expanding nozzles to the rotor, where it encounters two sets of moving blades and one set of fixed blades, passing thence to the exhaust. For the lower speed, the steam takes the same path through the blades as before, and is then led from the second set of moving blades into a group of blades consisting of two fixed and two moving sets. This arrangement gives a speed about half that due to the other, the reason being doubtless that, the expansion being carried through a longer stage, the drop in pressure at each set of blades is but half what it was before, with consequent proportional speed factor.—*Iron Age*.

SMELTING ZINC ORE IN THE BLAST FURNACE.

The experiments on the smelting of zinc ore in the blast furnace by the Lungwix process at Warren, N H., are shortly to be resumed and this season will be pushed to a definite conclusion, one way or another. It will be remembered that the physics of the process were recently discussed in two elaborate papers in the "Journal" by Mr. Gordon, chief engineer of the company which is testing the process. However, there are so many physico-chemical conditions involved in this problem as to which there are no available data, that it is impossible to arrive at any absolute conclusion from theoretical considerations, and the result must be determined by trial on a practical scale. Last year the work was unfortunately checked by a series of untoward accidents, which, however, were not unexpected in view of the boldness of the conception and entire novelty of the plant.—*Eng. and Min. Jour.*

LEAD PEROXIDE MANUFACTURE.

L. Frederich, E. Mallett and P. A. Guye, in *Monit. Scient.*, 1906, XX, pp. 514-518, state that normal or basic lead sulphate can be converted into lead peroxide with a nearly theoretical yield, by mixing it with magnesia, suspending the mixture in water, and passing in chlorine. In a trial with 5 kg. of lead sulphate in a rotating barrel of 25 liters capacity, the operation was completed in about three hours, and required: Water, 13 liters; magnesia, 1.2 kg.; and chlorine 1.2 kg. The crude reaction product obtained contains at least 90 per cent. of lead peroxide, and by purification first with caustic soda, and then with acid, a product of 97 per cent. purity can be obtained, containing only traces of chlorine. The cost of production of 100 kg. of lead peroxide is given as follows: 36 kg. of magnesia at 7 francs per 100 kg., 2.50; 3 kg. of chlorine at 15 francs per 100 kg., 4.95; 146 kg. of lead sulphate at 23 francs per 100 kg., 33.60; labor, etc., 3; total, 44.05 francs.—*Eng. and Min. Jour.*

ELECTRICAL SECTION.

(Stated meeting held Thursday, November 8th, 1906.)

The Physical Meaning of Power Factor and the Significance of a Power Factor Less Than Unity
Without Phase Difference.

BY ALBERT F. GANZ, M.E.,

Professor of Electrical Engineering at the Stevens Institute of Technology.

The power delivered to an electric circuit is at any instant equal to the product of the current strength in amperes, and the electromotive force or potential difference in volts, and this power is expressed in watts. With ordinary continuous currents the electromotive force and current strength remain constant for a finite time, and this constant electromotive force and current strength is indicated on a voltmeter and an ammeter suitably connected in the circuit. The product of the volts and amperes so indicated is the power in watts and is also constant.

With alternating currents the electromotive force and current strength are constantly changing in accordance with some periodic law. It is still true that the power is at any instant equal to the product of the volts and amperes at that instant. Alternating current voltmeters and ammeters do not indicate instantaneous values, but the *square root of the average squares* of these instantaneous values, which are called in practice the **effective* values. The average power is equal to the average of the products of the instantaneous volts and amperes, and

*In this article effective values of e. m. f. and current are designated by capital italics *E* and *I*, and instantaneous values by small italics *e* and *i*.

this average power in watts is in general less than the product of the effective volts and amperes. The factor by which this product of volts and amperes must be multiplied in order to obtain the true average watts is called the *Power Factor*. The true average power in watts can be directly indicated on a wattmeter suitably connected in the circuit. The Power Factor is then defined by the equation,

$$\text{Power Factor} = \frac{p}{I E} \quad (1)$$

and the simplest way to determine the Power Factor of an alternating current circuit is to measure I with an ammeter, E with a voltmeter and p with a wattmeter, and then to calculate the Power Factor by means of equation (1). The product of effective volts and amperes is generally called the *apparent power* or the *apparent watts*.

SINUSOIDAL WAVE FORMS.

The simplest and most common forms of electromotive force and current waves met in practice are sine waves. The effective value of a sine wave is equal to the maximum value, or amplitude, divided by the square root of two. In symbols,

$$E = \frac{e_m}{1.414} \quad (2)$$

With sine waves of electromotive force and current the Power Factor is numerically equal to the cosine of the angle of phase difference between electromotive force and current. With sine waves we can therefore write for the equation for power,

$$p = E I \cos \theta \quad (3)$$

In most treatises on alternating currents sinusoidal waves are assumed, and Power Factor is often defined as the cosine of the angle of phase difference.

We shall first consider the physical meaning of Power Factor in a circuit with sinusoidal electromotive force and current.

Let an alternating current generator be connected to a receiving circuit so that an alternating current flows through the circuit, and that power is delivered to and consumed by the cir-

cuit. If the sinusoidal electromotive force and current are in phase the angle of phase difference θ is zero, and $\cos \theta = 1$, and therefore the Power Factor is unity. The electromotive force, current and power curves for this case are shown in Fig. 1.

The power curve is a sinusoid of twice the frequency of the

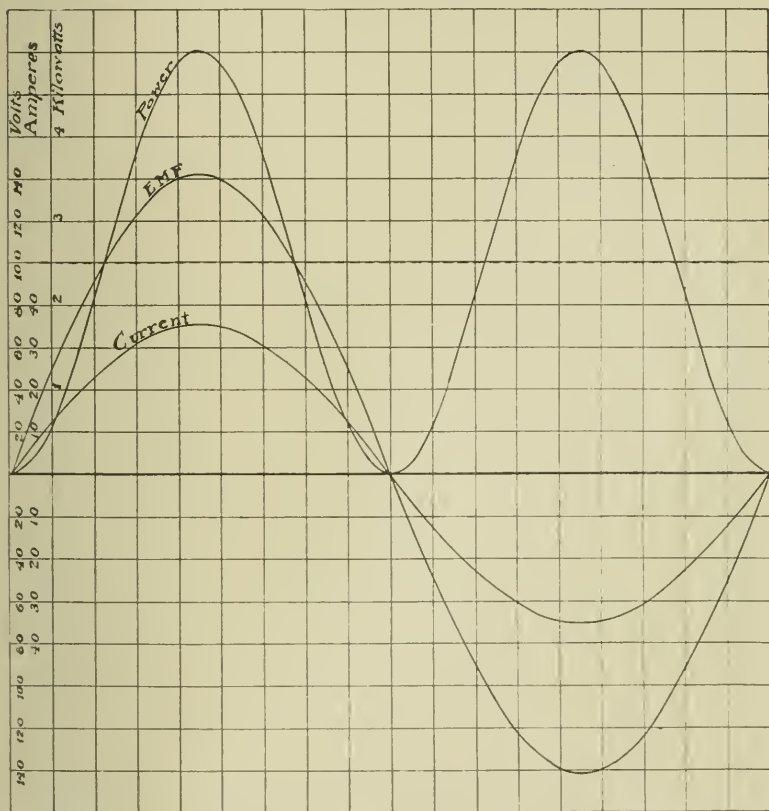


Fig 1—Sinusoidal electromotive force and current curves in phase, and the resultant power curve.

electromotive force and current curves and has only positive values. The physical meaning of this is that at every instant the generator delivers electrical energy to the circuit and this energy is consumed by the circuit. The average height of the power curve is the average power in watts and is in this case equal to the product of the effective volts and amperes.

If the sinusoidal electromotive force and current are in

quadrature the phase difference θ is 90° , and $\cos \theta$ is equal to zero, so that the average power delivered to the circuit is zero. The curves for this case are represented in Fig. 2.

It is seen that the power curve is again a sinusoid having twice the frequency of the electromotive force or current curves, but that its axis now coincides with the electromotive force and current axis, so that there are alternately positive and negative power loops of equal area. The physical mean-

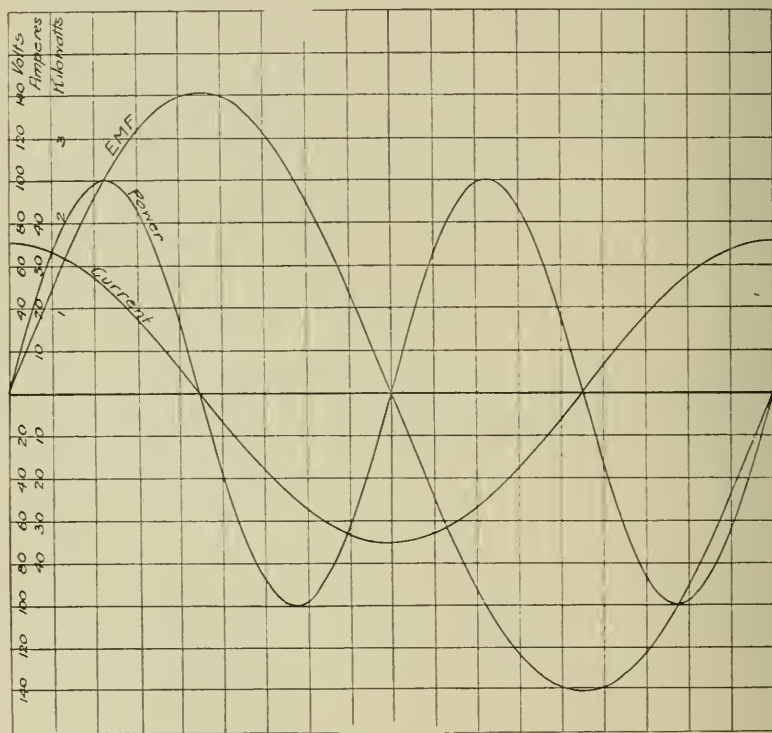


Fig. 2—Sinusoidal electromotive force and current curves in quadrature, and the resultant power curve.

ing of this is that for that half of each half period during which the electromotive force and current are in the same direction the generator delivers energy to the circuit, and this energy is all stored in the reactance of the circuit, and that during the next half of each half period where electromotive force and current are in opposite directions this stored energy is returned from the circuit to the generator driving it as a motor. The

average height of the power curve is the average power and is in this case equal to zero.

If the sinusoidal electromotive force and current differ θ degrees (always less than 90°) in phase, the curves for electromotive force, current and power take the form shown in Fig. 3.

The power curve is again a sinusoid of double frequency, but

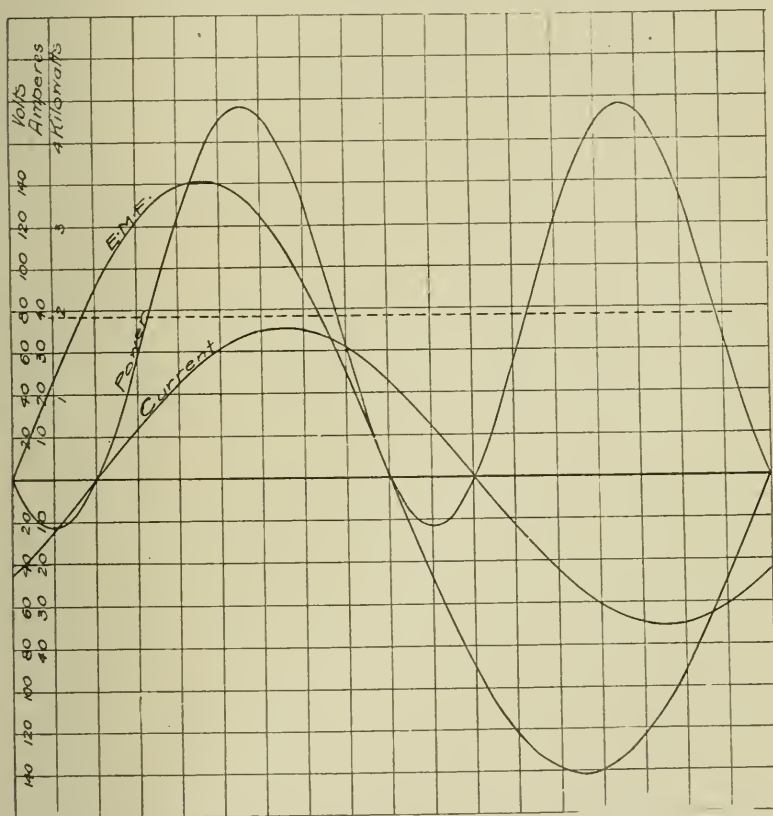


Fig. 3—Sinusoidal current lagging behind a sinusoidal electromotive force, and the resultant power curve.

the positive area is now greater than the negative area. The physical meaning of this is that during the (greater) part of the half period where current and electromotive force are in the same direction, the generator delivers energy to the circuit and part of this energy is consumed by the circuit, and a second part is stored in the reactance of the circuit; during the (less) part of the half cycle where current and electromotive force are

opposite in direction this stored energy is returned from the circuit to the generator driving it as a motor. The average height of the power curve is the average power in watts, and is in this case equal to the product of the effective volts, the effective amperes, and the cosine of the angle of phase difference between electromotive force and current.

With sinusoidal electromotive force and current, a Power Factor less than unity signifies therefore that there is a phase difference between the electromotive force and current, and that during a part of each half cycle some of the electrical energy delivered by the generator is stored in the circuit, which portion is again returned during the next half cycle from the circuit to the generator, driving the latter as a motor and delivering energy to the fly wheel.

This discussion of power pulsation between the dynamo and the circuit has been applied to a single phase system. It applies, however, equally to each one of the phases of a polyphase system; in a balanced polyphase system the power pulsations of the individual phases overlap so that there is always resultant generator action requiring a constant driving torque.

WAVE FORMS WHICH ARE NOT SINUSOIDAL.

In alternators the north and south poles of the field magnets are practically always similar and symmetrical, and the armature inductors moving with uniform angular velocity relative to these poles have alternating electromotive forces induced in them which have exactly similar positive and negative loops. The distorting influence of circuits also always acts in the same way upon the two loops. The alternating electromotive force and current waves met in practice have therefore practically always exactly similar positive and negative loops.

It has been shown by Fourier that any periodic wave can be resolved into or made up of a fundamental sine wave and a series of harmonics. When a periodic wave has its positive and negative loops similar, it can only contain odd harmonics, because the effect of even harmonics is to change the form of the negative from the positive loops. The general expression

for any electromotive force wave can therefore be written as a series with only odd harmonics, giving the expression,

$$e = \sum e_n \sin n (\omega t - a_n) \quad (4)$$

$$= e_1 \sin (\omega t - a_1) + e_3 \sin 3 (\omega t - a_3) + e_5 \sin 5 (\omega t - a_5) + \text{etc.} \quad (5)$$

in which

e = instantaneous value of electromotive force.

e_1 = maximum value or amplitude of the fundamental wave.

e_n = maximum value or amplitude of the n^{th} harmonic.

a_n = phase position of e_n expressed in degrees of the fundamental wave.

In the same way we have for the general expression of any alternating current wave

$$i = \sum i_n \sin n (\omega t - b_n) \quad (6)$$

$$= i_1 \sin (\omega t - b_1) + i_3 \sin 3 (\omega t - b_3) + i_5 \sin 5 (\omega t - b_5) + \text{etc.} \quad (7)$$

in which i_n is the amplitude of the n^{th} harmonic, and b_n the phase position of i_n .

Alternating current voltmeters and ammeters indicate effective values of irregular electromotive force or current waves. The effective value of an irregular wave is equal to the square root of one half the sum of the squares of the amplitudes of its harmonic components. In symbols,

$$I = \sqrt{\frac{i_1^2 + i_3^2 + i_5^2 + \text{etc.}}{2}} \quad (8)$$

similarly
$$E = \sqrt{\frac{e_1^2 + e_3^2 + e_5^2 + \text{etc.}}{2}} \quad (9)$$

Substituting for the amplitudes the corresponding effective values of the harmonic components by means of equation (2) we obtain

$$I = \sqrt{I_1^2 + I_3^2 + I_5^2 + \text{etc.}} \quad (10)$$

and
$$E = \sqrt{E_1^2 + E_3^2 + E_5^2 + \text{etc.}} \quad (11)$$

The power developed by an irregular electromotive force and current wave is equal to the average of the instantaneous

products of volts and amperes, and this average product would be indicated on a wattmeter suitably connected in the circuit.

Since the average product of any two harmonic waves of different frequencies is equal to zero when taken over a complete cycle of the lower frequency, it follows that only harmonic components of electromotive force and current of the same frequency can produce resultant power. The resultant power of irregular electromotive force and current waves is therefore equal to the sum of the products of the effective values of the synchronous harmonic electromotive force and current components and the cosines of their respective angles of phase difference. In symbols

$$p = E_1 I_1 \cos \theta_1 + E_3 I_3 \cos 3 \theta_3 + E_5 I_5 \cos 5 \theta_5 + \text{etc.} \quad (12)$$

in which $\theta_n = (a_n - b_n)$, that is the angle of phase difference between e_n and i_n expressed in degrees of the fundamental wave. Equation (12) may be written in terms of the amplitudes of the harmonics of electromotive force and current, so that

$$p = \frac{e_1 i_1}{2} \cos \theta_1 + \frac{e_3 i_3}{2} \cos 3 \theta_3 + \frac{e_5 i_5}{2} \cos 5 \theta_5 + \text{etc.} \quad (13)$$

Since Power Factor is by definition, the ratio of true watts to apparent watts, we can write the general equation for Power Factor from equations (5), (7) and (13)

$$\text{P. F.} = \frac{\frac{1}{2}(e_1 i_1 \cos \theta_1 + e_3 i_3 \cos 3 \theta_3 + e_5 i_5 \cos 5 \theta_5 + \text{etc.})}{\frac{1}{2}\sqrt{(e_1^2 + e_3^2 + e_5^2 + \text{etc.}) (i_1^2 + i_3^2 + i_5^2 + \text{etc.})}} \quad (14)$$

and in effective values

$$\text{P. F.} = \frac{(E_1 I_1 \cos \theta_1 + E_3 I_3 \cos 3 \theta_3 + E_5 I_5 \cos 5 \theta_5 + \text{etc.})}{\sqrt{(E_1^2 + E_3^2 + E_5^2 + \text{etc.}) (I_1^2 + I_3^2 + I_5^2 + \text{etc.})}} \quad (15)$$

These are the most general expressions for Power Factor, and show that with irregular electromotive force and current waves the Power Factor is a function of the amplitudes and phase positions of the harmonic components of the electromotive force and current waves. It can be shown mathematically that the numerator of equation (14) can never be greater than the

denominator, from which it follows that Power Factor can never have a greater value than unity.

Since the maximum value of a cosine is unity it follows that for $\cos \theta_n = 1$, equations (14) and (15) will be a maximum; this means that the Power Factor is a maximum when the synchronous harmonic components of electromotive force and current are in phase. Equations (14) and (15) for Power Factor then simplify to

$$\text{P. F.} = \frac{e_1 i_1 + e_3 i_3 + e_5 i_5 + \text{etc.}}{\sqrt{(e_1^2 + e_3^2 + e_5^2 + \text{etc.}) (i_1^2 + i_3^2 + i_5^2 + \text{etc.})}} \quad (16)$$

and

$$\text{P. F.} = \frac{E_1 I_1 + E_3 I_3 + E_5 I_5 + \text{etc.}}{\sqrt{(E_1^2 + E_3^2 + E_5^2 + \text{etc.}) (I_1^2 + I_3^2 + I_5^2 + \text{etc.})}} \quad (17)$$

When an irregular electromotive force wave is applied to a circuit with constant resistance and zero reactance an irregular current wave is produced whose instantaneous values are in a constant ratio with the contemporaneous values of the electromotive force. This current wave contains the same harmonic components as the electromotive force wave; and these components are in phase with and in a constant ratio with the corresponding harmonic components of the electromotive force wave; this constant ratio is expressed by

$$\frac{E_1}{I_1} = \frac{E_3}{I_3} = \frac{E_5}{I_5} = \text{etc.} = R \text{ (constant)} \quad (18)$$

which is evidently the resistance of the circuit.

From (18)

$$E_1 = RI_1, E_3 = RI_3, E_5 = RI_5 \text{ etc.}$$

which substituted in (17) gives

$$\begin{aligned} \text{P. F.} &= \frac{R(I_1^2 + I_3^2 + I_5^2 + \text{etc.})}{\sqrt{R^2(I_1^2 + I_3^2 + I_5^2 + \text{etc.}) (I_1^2 + I_3^2 + I_5^2 + \text{etc.})}} \quad (19) \\ &= 1 \end{aligned}$$

The Power Factor of a circuit with constant resistance and zero reactance is therefore unity no matter how irregular the applied electromotive force wave may be. An exception to this would be the case of a circuit containing a counter elec-

tromotive force from a separative source, in which the Power Factor would in general be less than unity.

Another way to state this result is to say that with an irregular electromotive force and current wave the Power Factor can only be unity if the instantaneous values of electromotive force and current are in a constant ratio, that is, if the same harmonics are present in both waves and are in phase and have their amplitudes in a constant ratio.

Irregular electromotive force and current waves having different harmonics or having synchronous harmonics whose amplitudes are not in a constant ratio produce a Power Factor less than unity, the value of which may be calculated by means of equations (14) or (15).

A common example of irregular waves is furnished by the electric arc, in which the current is distorted because the resistance of the arc is not constant but is a function of the current. *Curves of electromotive force, current and power, for a mineralized carbon open arc, are shown in Fig. 4. The potential differences are taken across the arc.

It will be noticed that the electromotive force and current curves cross the time axis at the same point and may in this sense be said to be in phase, and the power curve has only positive values. The Power Factor for this arc is 0.85. The lowering of the Power Factor is due to the presence of harmonic components in the current or electromotive force wave for which there are no synchronous harmonic components in the other, and may also be due to phase difference between synchronous harmonic components of electromotive force and current.

In practice it frequently happens that the electromotive force curve is sinusoidal and the current which it produces is distorted. The expression for power is for this case obtained from equation (12) by making E_3, E_5 , etc., equal to zero, giving,

$$p = E_1 I_1 \cos \theta_1 \quad (20)$$

which shows that only the fundamental of the current curve

*The curves of electromotive force and current are copied from an oscillogram, given by A. Blondel in a paper before the International Electrical Congress in 1904.

produces real power, while the upper harmonic components of the current curve produce wattless power. The expression for Power Factor for this case is similarly obtained from equation (14), giving

$$\text{P. F.} = \frac{E_1 I_1 \cos \theta_1}{E_1^2 (I_1^2 + I_3^2 + I_5^2 + \text{etc.})} \quad (21)$$

which simplifies to

$$\text{P. F.} = \frac{I_1}{I} \cos \theta_1 \quad (22)$$

Equation (22) shows that distortion of the current with sinu-

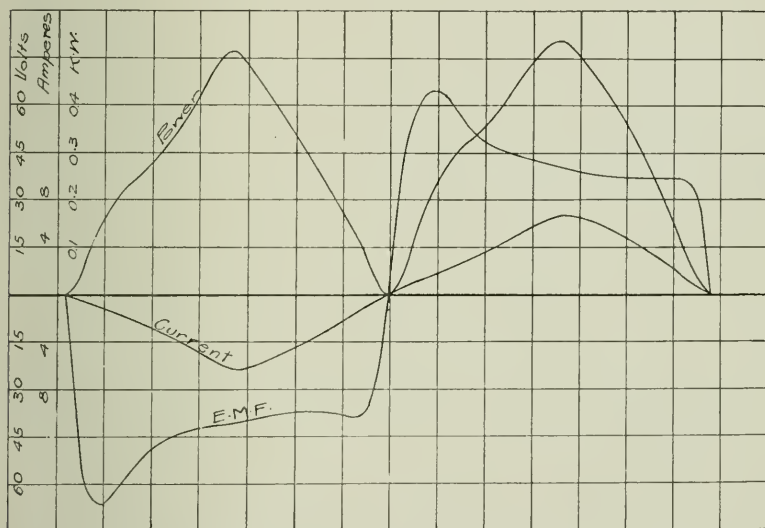


Fig. 4—Curves of potential difference, current and power for an open arc with mineralized carbons

soidal electromotive force has the effect of lowering the Power Factor.

A practical example of a sinusoidal electromotive force and distorted current is illustrated in Fig. 5.

The values of electromotive force and current for these curves were obtained by experiment* from the supply circuit

*The data for the mercury vapor rectifier are taken from experiments made in the Department of Electrical Engineering of Stevens Institute by

of a single phase Cooper Hewitt mercury vapor rectifier operating on a 60 cycle supply circuit and charging a battery of storage cells. The electromotive force curve is sinusoidal except for a slight distortion near the zero points which is due to armature reactance; this difference from a sinusoidal wave is neglected. The current curve is considerably distorted, due mainly to the shifting of the vapor stream from one anode to the other near the zero points of the supply electromotive force and to the action of the sustaining coil. The fundamental of the current wave has been found by analysis and is shown in the diagram. The following values were found for these curves:

Supply voltage, effective.....	$E = 102.9$
Supply current, effective.....	$I = 11.5$
Apparent watts	$E I = 1183$
True watts	$P = 1100$
Power Factor.....	$P \div E I = 0.93$
Effective value of fundamental of current.....	$I_1 = 11.4$
Phase difference between E and I_1	$\theta_1 = 20^\circ$
$\cos \theta_1$	$= 0.94$

Calculating the Power Factor from equation (22) we get

$$\text{P. F.} = \frac{I_1}{I} \cos. \theta_1 = \frac{11.4}{11.5} \times 0.94 = 0.931$$

which agrees well with the value found above by dividing true watts by apparent watts. The lowering of the Power Factor

Messrs. L. A. Hazeltine, G. Crisson, P. J. Howe, A. F. Ernst and E. F. English, in connection with their graduating theses.

A convenient graphical method for analyzing irregular waves was devised by Mr. L. A. Hazeltine while working on his thesis. This method was also applied to finding effective values and average power. A description of the method is given in the October, 1906, issue of the *Stevens Institute Indicator*.

The effective values of current and electromotive force obtained from the a.c. instruments (hot wire and dynamometer types) in some cases did not agree with the values calculated from the waves. The discrepancies were probably due to errors in the instruments, due possibly in some cases to the peculiar wave shapes. The values calculated from the waves were used in the calculations. The readings of the d.c. instruments (Weston type) and of the wattmeters (Weston type) generally agreed well with the corresponding values calculated from the waves.

from 0.94 to 0.93 is therefore due to distortion of the current wave.

If the fundamental of the current wave is in phase with the electromotive force, equation (22) for Power Factor becomes

$$\text{P. F.} = \frac{I_1}{I} \quad (23)$$

and is therefore less than unity, and equal to the ratio of the

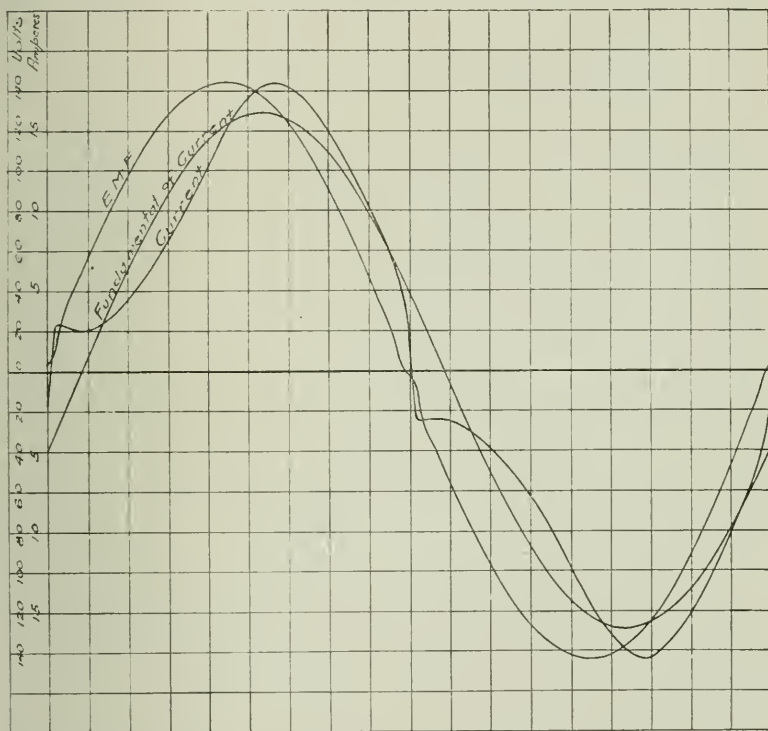


Fig. 5—Curves of electromotive force and current from the supply circuit of a Cooper Hewitt mercury vapor rectifier with storage battery load and also the fundamental of the current wave.

effective value of the fundamental wave to the effective value of the distorted wave. The harmonics in the current wave produce zero resultant power with the electromotive force wave.

An example of an harmonic electromotive force and distorted current in phase is given in Fig. 6. The values are assumed for illustration and have not been obtained by experiment.

The effective value of the electromotive force is 100 volts. The distorted current is made up of a fundamental $I_1 = 25$ amperes (effective) and a third harmonic $I_3 = 10$ amperes (effective), both being in phase with the electromotive force. The effective value of the actual current is therefore $I = \sqrt{25^2 + 10^2} = 26.92$ amperes. The apparent power is $I \times E$

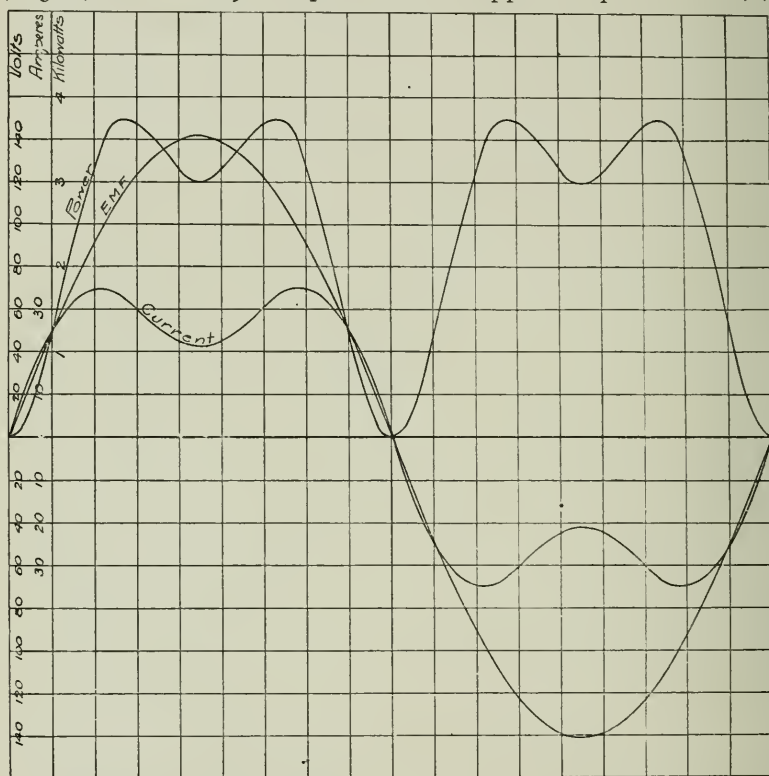


Fig. 6—Sinusoidal electromotive force and distorted current consisting of a fundamental and the third harmonic in phase with the electromotive force, and the resultant power curve,

$= 2692$ watts. The true power is $I_1 \times E = 2500$ watts. The Power Factor is therefore $2500 \div 2692 = 0.93$. The Power Factor can also be calculated from I_1 and I by means of equation (22), giving

$$\text{P.F.} = I_1 \div I = 25 \div 26.92 = 0.93$$

as found before. The lowering of the Power Factor from 1 to 0.93 is in this case entirely due to distortion of the current

curve. If the phase position of this third harmonic were shifted and combined with the same fundamental sine wave of current the resultant distorted current curve would have a very different shape and would cross the time axis at a different point from the crossing of the electromotive force curve. The average power and the Power Factor would however remain the same as before.

PULSATING CONTINUOUS CURRENTS.

The continuous currents obtained from alternating currents by means of rectifiers are not of constant value but are pulsating; a single phase rectifier produces generally considerable pulsations in the rectified current, while two and three phase rectifiers produce a more nearly constant current. A pulsating current is equivalent to a continuous current of constant value and a superimposed alternating current. The laws of alternating currents must therefore be applied to pulsating currents. A direct current ammeter or voltmeter of a type which does not respond to alternating currents will indicate the average or mean value of a pulsating current or electromotive force; an alternating current ammeter or voltmeter of a type which is correct also on direct current will indicate the effective value of a pulsating wave. The effective value of a pulsating wave is always greater than the average value.

If the pulsating electromotive force and current are measured in a circuit with constant resistance and zero reactance and zero counter electromotive force the product of the effective volts and amperes is the true average power in watts. This case is similar to the one discussed in connection with equation (19) in the first part of this paper.

If the pulsating electromotive force and current are measured in a circuit containing reactance, or a constant counter electromotive force such as a charging storage battery, or a resistance which is a function of the current, such as arc lamps, the product of the effective volts and amperes gives the apparent watts, which, however, is greater than the true watts; the true watts must be measured with a wattmeter. The true watts divided by the apparent watts is the Power Factor. It

is therefore seen that a circuit with a pulsating continuous current may have a Power Factor less than unity.

An example of a pulsating electromotive force and current is illustrated in Fig. 7, in which the curves represent the rectified current from a single phase mercury vapor rectifier, charging a battery of storage cells and having also a regulating rheostat in series. The values of electromotive force and cur-

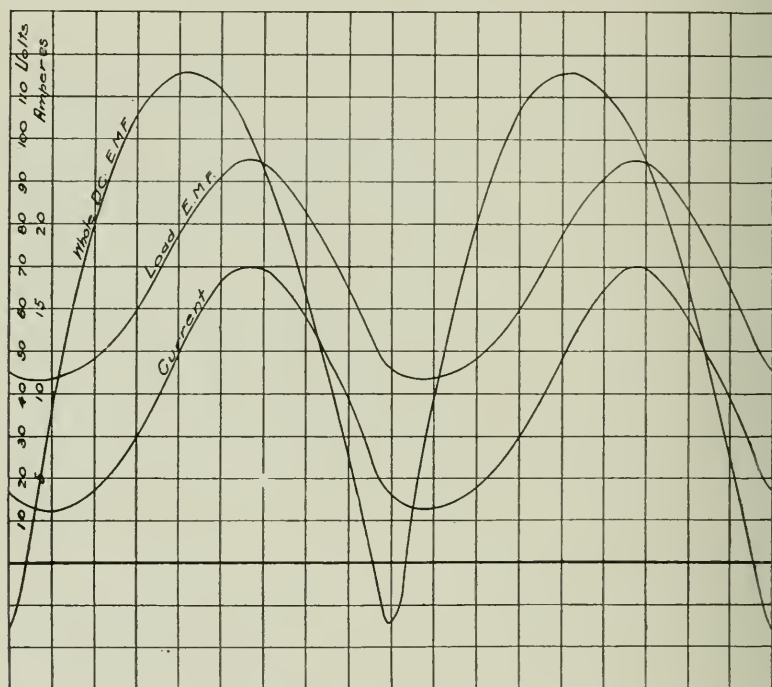


Fig. 7—Curves of electromotive force and current from the rectified current circuit of a single phase mercury vapor rectifier charging a battery of storage cells.

rent were obtained by experiment and correspond to the curves of supply electromotive force and current shown in Fig. 5 for the same rectifier. One of the electromotive force curves represents the potential difference across the storage battery and rheostat, or load, and the other the potential difference across the load and the sustaining coil, or the entire d.c. circuit. The following are the values for the circuit of the rectified current:

Average p.d. across total d.c. circuit.....	= 68.7
Effective p.d. " " " "	$E_2 = 80.3$
Average current.....	$i_{\text{aver}} = 9.9$
Effective current.....	$I = 11.1$
Apparent watts, total d.c. circuit.....	$E_2 I = 891$
True watts " " "	$p_2 = 800$
Power Factor of " " "	$p_2 : E_2 I = 0.898$
Average p.d. across load.....	= 67.9
Effective p.d. across load.....	$E_1 = 69.8$
Apparent watts in load.....	$E_1 I = 775$
True watts in load.....	$p_1 = 759$
Power Factor of load.....	$p_1 : E_1 I = 0.98$

It should be stated that the resistance loss in the battery and rheostat was in this test greater than the useful energy stored in the battery.

The Power Factor of the entire d.c. circuit is seen to be considerably less than unity, on account of the effects of the sustaining coil and of the constant counter electromotive force of the battery in altering the shapes of the waves. That is, the instantaneous values of the electromotive force and current are not in a constant ratio as required for unity Power Factor. (See equation (19)). The Power Factor of the load is also less than unity for the same reason. This Power Factor would have been lower if the resistance loss had been a smaller part of the load.

It will be noticed that the average values of the pulsating electromotive force and current, as indicated on direct current instruments, are considerably less than the corresponding effective values, as indicated on the alternating current instruments. The product of the average volts and amperes is therefore not the average power. The reason for this lies in the mathematical fact that the average product of two sets of numbers is not equal to the product of their average values. In a circuit with pulsating current the average power should therefore be measured by means of a wattmeter.

In the case of a storage battery charging with a pulsating current, the average current as indicated on a d.c. ammeter is the true charging current, and this average current multiplied by the time, gives the ampere-hours of charging, and this ampere-hours multiplied by the constant counter electromotive

force of the battery gives the watt-hours which is stored as chemical energy in the battery.

RESUMÉ.

Power Factor, as defined by the ratio of true to apparent watts, is in general less than unity, and can never have a value greater than unity.

In circuits with distorted alternating electromotive force and current waves the Power Factor is determined by two components, first, the angles of phase difference between synchronous harmonic components of electromotive force and current (as determined from Fourier's series), and, secondly, by the variation from proportionality of the harmonic components of the waves. The component of Power Factor which is due to phase difference has the physical significance that there is a corresponding surging of energy between the dynamo and the circuit. The other component, due to the variation from proportionality of the waves, represents an apparent surging of energy but has no real physical significance, and is in other words due to the mathematical fact that the average of the products of the instantaneous values of two waves is in general less than the product of their effective values.

With irregular wave shapes the phase position is sometimes measured from the zero points of the waves and sometimes from the maximum points; the latter has the disadvantage that the maximum point is not well defined and that some waves have more than one maximum point. The author has preferred therefore to use the zero points from which to measure phase position.

It should be noted that the phase difference between irregular waves of alternating current and electromotive force, as measured between their zero points, does not bear a direct relation either to the power or to the Power Factor of the circuit. It has been shown that two irregular waves may be in phase, that is cross the time axis at the same points, and yet have a low Power Factor. Similarly two irregular waves may be considerably out of phase, that is cross the time axis at different points some distance apart, and yet the Power Factor may be greater than the cosine of this angle of phase difference

between the irregular waves. The reason for this lies in the fact that certain harmonics alter the wave shapes near the zero points of the irregular waves so that these zero points of the irregular waves are shifted considerably from the zero points of their fundamental sine components, and the latter are generally the principal elements which determine the power and Power Factor. The ordinary alternating current arc is a good example of distorted electromotive force and current in phase, and yet having a low Power Factor.

In the special case of a sinusoidal electromotive force and distorted current, which is of frequent occurrence in practice, the Power Factor is the product of two factors (equation (22)), one factor being the cosine of the angle of phase difference between the fundamental sine wave of current (as determined from Fourier's series) and the electromotive force, and the second factor being the ratio of the effective value of this fundamental sine wave of current to the effective value of the distorted current wave.

The supply circuit of a mercury vapor rectifier is a good example of distorted current produced with sinusoidal electromotive force. In the example given this distorted current was very nearly in phase with the electromotive force, but the Power Factor was 0.93. It was shown that the fundamental sine component of the distorted current was considerably out of phase with the electromotive force, due to the harmonics in the current, and the lowering of the Power Factor was principally due to the phase difference between this fundamental sine component and the electromotive force.

If the Power Factor of a circuit is low on account of phase difference between current and electromotive force it is possible to raise the Power Factor to unity by connecting a suitable reactance or a synchronous machine in shunt with the circuit. If the Power Factor is low on account of wave distortion it cannot be raised by shunted reactance. If the Power Factor of a circuit is low both on account of phase difference and of wave distortion it can only be corrected by shunted reactance for that part which is due to phase difference. In most practical cases wave distortion does not produce serious lowering of Power Factor. Certain kinds of apparatus, such as rectifiers and alternating current arc lamps, produce con-

siderable distortion of the current waves and such apparatus may have inherently a poor Power Factor.

The author's thanks are due to Mr. G. Crisson, Assistant in the Department of Electrical Engineering of Stevens Institute, for help in analyzing waves, and for valuable suggestions, and also to Mr. Percy H. Thomas, of the Cooper Hewitt Electric Co., for valuable suggestions.

THE NEED FOR CORUNDUM.

Never in the history of the abrasive industry has the time been more opportune for the development of corundum properties than at present when there is a scarcity of emery ore.

During 1905, the production of corundum and emery in the United States, according to Mr. Joseph Hyde Pratt, who has written a report on the production of abrasive materials for the United States Geological Survey, amounted to 2126 short tons, valued at \$61,464, as compared with 1916 short tons, valued at \$56,985 in 1904, an increase of 210 tons in quantity and of \$4,479 in value. The corundum mined was from North Carolina and Montana and the emery from New York and Massachusetts.

The Greek and Turkish deposits are not furnishing the grade of emery that is desired, nor the quantity, and this has also been true during the past year of the emery mines in this country. The Canadian corundum deposits supply to some extent the demand for corundum, but there is still a large enough market to warrant the working of deposits in this country.

The importation of corundum and emery into the United States is still largely in excess of the home production. In 1905 these imports were valued at \$347,425 against \$260,424, the value in 1904.

SOFT GRAPHITE MADE ELECTRICALLY.

Edward G. Acheson, of Niagara Falls, N. Y., has announced that he has discovered a process for making unctuous or soft graphite. Heretofore, the graphite made by the International Acheson Company has been hard graphite, and has been applied to a field not entered by the natural graphites, such as in the manufacture of electrodes, as a battery filler, and as a paint pigment. The soft graphite will be used as a lubricant, as a stove polish and also for coating gunpowder, which is tumbled in graphite to coat or face it. It will also be used for electrotyping.

As it can be manufactured at comparatively low cost, it is expected that the new, soft graphite will become a successful competitor of natural graphite. The product of the experimental furnaces has been very satisfactory as to uniformity. Mr. Acheson predicts that within a few years the manufacture of artificial graphite will be the largest industry at Niagara Falls.—*Eng. and Min. Jour.*

Mining and Metallurgical Section.

*(Stated Meeting, held Thursday, October 18, 1906.)***Acoma : the Cliff City of New Mexico.***

BY PROF. OSCAR C. S. CARTER.

One of the strangest corners of our country and one of the greatest wonders of the Southwest is Acoma, the Cliff City, built centuries before Columbus' time and to-day occupied by the Pueblo Indians, who are the descendants of those conquered by Coronado's expedition 366 years ago. It is the oldest city in the United States and has been inhabited continuously for centuries. Man in every country on the globe is undoubtedly influenced by his environments; this statement holds true with the Indian, African and Mongolian alike, and to a less degree perhaps with civilized man. The conceptions of the Indian by the English and Spaniards were totally different. The cavaliers who sailed up the broad estuaries of the Delaware and Chesapeake and the Puritains who landed on New England's inhospitable shore met a more or less migratory race of Indians who subsisted by hunting and fishing. Many of them were born warriors. The same may be said of the former Indians of the plains who were migratory and warlike. The buffalo was their food supply, and when the white man, with little foresight and less sense, almost exterminated this animal, the food supply of the Indian was destroyed; starvation stared him in the face, and the Government has been obliged to give him an allowance of flour and meat ever since at his new home on the Indian reservation. How different was the experience of the Spaniards who came from Mexico in 1540 with Coronado's expedition in search of the seven cities

*Read by title.

of Cibola? In their conquering march through the Southwest they met a peaceful and agricultural race of Indians, the Zunis, Acomas and Hopis, who were not migratory and were not hunters, but lived in permanent houses of stone on the mesas and in the canons hundreds of years before the discovery of America. In the valleys and at the base of the mesas they raised melons, pumpkins and corn. They are the Pueblo Indians of to-day. They were not hunters, because in the arid and desert district of the Southwest, where they live, there is little to hunt. They were forced to be agriculturists, notwithstanding a harsh environment and deficient rainfall of but ten or twelve inches per year. The Government did not take their land because nobody wanted it. It is not worth having. So they have remained unmolested for centuries in their isolated desert homes. They were not born warriors, although they defended themselves strenuously and often successfully in their impregnable homes against the terrible Apaches and the war-like Navajos, who were migratory. Farther south, near the Mexican boundary line, the Papagos have a still harsher environment, and even less rainfall, and they are reduced to the extremity of living on mesquite beans, seeds and the pulp of the giant cactus, Saguaro. The first spring shower finds them planting a little corn which often fails to reach maturity. The Pai Utes, near Death Valley, California, do not scorn a meal of lizards and snakes. Man's environment influences his whole life, and the proper way to study man is as influenced by his environment. Acoma is located about three miles south of the enchanted mesa, near the southeast boundary of the plateau country, which was described in the previous article on the Enchanted Mesa by the author. It is in the Pueblo region. The ancient Pueblo region, according to Cosmos Mindeleff (19th Annual Report, Bureau Ethnology, Part II,) "extends from Great Salt Lake to beyond the southern boundary of the United States, and from the Grand Canyon of the Colorado River to the vegas or plains east of the Rio Grande and the Pecos. Within this area of about 150,000 square miles ruins can be numbered almost by the thousands." In other words, the present Pueblo Indians and their ancestors, the so-called Cliff Dwellers, dwelt in Utah, Arizona, New Mexico and Southwest Colorado. They occupied all of the plateau region and the

country to the south of it, extending over the boundary line into Mexico. Mindeleff states (13th Annual Report, Bureau of Ethnology, page 258,): Before archeological investigation of the Pueblo region commenced and when there was little knowledge extant by which travelers could check their conclusions, the immense number of ruins in that region was commonly attributed to an immense population, some writers placing the number as high as 500,000. Besides this figure the present population, about 9000, is so insignificant that it is hardly surprising that the ancient and modern villages were separated and attributed to different tribal stocks. It is very doubtful whether the total number of Pueblo Indians ever exceeded 30,000. This is the figure stated by Mr. A. F. Bandelier, whose intimate acquaintance with the eastern part of the Pueblo region gives his opinion great weight. The apparently trifling causes which sometimes result in the abandonment of villages has been alluded to. He reconciles the small population to the thousands of ruins as follows: "Migration among the Pueblo Indians means a slow, gradual movement without any definite end in view. A section of a village moves away from the parent village only a few miles; another section moves to another site. These movements are not possible where outside hostile pressure is great, and if such pressure is long continued, it results in a reaggregation of the various scattered settlements into one large village. Such, in brief, is the process which is termed migration and which has covered the Southwest with thousands of village ruins. As a rule the abandonment of villages was a gradual process, often consuming years. Migration, he says, must not be taken in the sense in which it has been applied to European stocks, a movement of people en masse or in several large groups." The present Pueblo Indians, the descendants of these ancient people, are not migratory. The Pueblo villages of Zuni, Acoma and Oraibe have been inhabited for centuries.

Acoma is thirteen miles south of the Pueblo village of Laguna, which is located along the Atlantic and Pacific R. R., now known as the Atchison R. R. It is also about ninety miles west of Albuquerque. We made the start from Laguna where we secured good accommodations with Mr. Marmon. His son, a graduate of Carlisle, drove us to Acoma. The



Acoma mesa in the distance. Only water in the desert, on the road to Acoma.



Where the trail begins at Acoma sand dunes 80 feet high.

(Carter)



A break or reentrant in the mesa near the corral.



Climbing up the steep trail to Acoma.

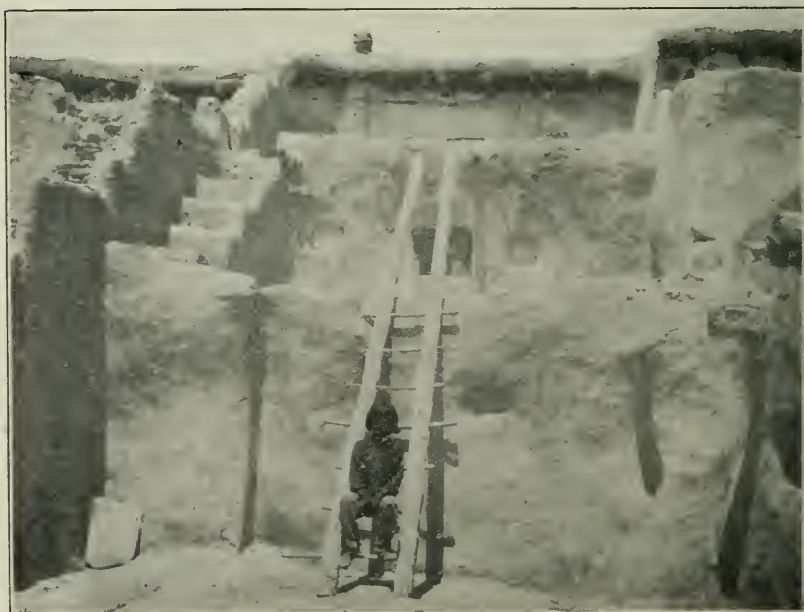
Valley of Acoma and the Enchanted Mesa were described by the author in a previous article. It was rather a hot journey to make in an open wagon across the desert in July. Our water gave out before reaching Acoma and one of our horses, that had evidently been driven hard the day before, fell over from fatigue; the heat and the journey through the deep sand in places were too much for him. Otherwise the journey was uneventful and fairly comfortable. There is but one water hole on the journey to Acoma where water can be obtained for horses; it is not far from the Enchanted Mesa. It is a circular pond about an acre in extent which looks very like a so-called limestone sink, although the surface rock is sandstone. This water is too alkaline for man, but the horses seemed glad to get it. The cattle and what horses and mules the Acoma Indians possess graze on the gramma grass of the valley. This is a common name for several low grasses found in Arizona, New Mexico, Texas and also on the plains east of the Rockies. Mesquite grass and buffalo grass come under this heading. Cattle and sheep are not particular in the West where many of the ranges have been destroyed by putting too many cattle or sheep on a given area. Sheep will even eat sage brush and seemingly thrive on it. The stock near Acoma always frequent this water hole. On the road near Laguna we crossed one of the numerous tributaries of the Rio Grande, which at that point is merely a sluggish alkaline creek, unfit for man or beast. One writer has called this the Rio Puerco River, which is an error, as this river is in Arizona and is a tributary of the Colorado Chiquito, or Little Colorado. We had better say, perhaps, that it is an error for the geographers to correct, as the maps show two rivers of the name Rio Puerco, one in Arizona and the other in New Mexico. The mesa on which Acoma is built rises from 350 to 400 feet above the desert. The walls are generally vertical. The two trails in general use are the horse trail and a trail the Indians use, which stands at an angle of about 50 degrees and in some places is vertical. This is a very trying and steep climb on a hot day. You first climb up some sand dunes, which are from 70 to 80 feet high. One is astonished at these enormous dunes, which seem out of place at the base of this mesa. The sand is formed by the disintegration of the sandstone rock and

is heaped up by the strong wind. On the vertical trail are some ladders, simply cedar posts with rungs, although in some places pieces of wood are wedged between rocky walls and serve as ladders; in other places steps were cut in the rock which necessitated steep climbing. The Indians told the following story to a writer (in *American Architect*, Vol. 16, page 258): "Several Indians started up the steep trail, each with a live sheep on his back. When they had nearly reached the top, the sheep carried by the foremost man became restless, and the shepherd in his excitement lost not only his hold but also his footing and toppled over, sweeping his companions down on the jagged rocks below where they fell in a lifeless heap. The Indians have carved a representation on the rock near where it occurred, which scarcely serves to steady the nerves."

The trail is steep enough, but we don't want to give the impression it is too bad, because the Indian boys run up and down like squirrels, and my chief concern was the fear of starting a loose boulder down the trail after them. When you reach the flat summit of the mesa you are astonished to find three parallel rows of houses extending for a distance of from 800 to 1000 feet across the mesa. There are two fairly wide streets between the rows. These long unbroken walls of stone and adobe extending across the mesa are divided by partition walls at right angles into separate homes. Imagine a sheer wall of solid masonry on one side of the street and terraced house three stories high, like a series of steps, on the other. These terraces are reached by ladders and the highest roof or terrace is about 35 feet from the ground. The wall of the first row of houses rises sheer from the cliff and is a continuation of its face. This wall faces the north and the terraced part of the houses faces south. It would not be safe for a man giving to sleep-walking to wrap himself in a Navajo blanket and lie down near the wall, because if he should fall it would be a sheer drop of nearly 400 feet. We climbed up the ladder to the terraces and entered one of the rooms. It was clean and smooth like a plastered room. A stocky built, heavy featured Indian was reclining on the floor; a middle-aged, bare-footed Pueblo woman, who was standing near by, grunted welcome. A white-haired, feeble old Indian, who was nearing the century mark, rose slightly from a reclining position and held out



The old Spanish church at Acoma; walls seven feet thick.



A young man of the Acoma tribe in front of his terraced home.

(Carter)



A street in Acoma.



Bargaining for a necklace of beads.

his hand in welcome. He was either a former governor or else the cacique, who is the oldest man in the tribe, whose duty it is to treasure in memory's storehouse all the traditions, lore and history of the tribe. He is, in fact, the official historian, and to the young man who is to succeed him he tells everything he knows concerning the history and tradition of the tribe.

They have store rooms and living rooms in which you will find jerked meat, dried peaches, muskmelons and peppers, skins of animals and some silver filagree work and their wearing apparel. The walls and fire-place are adobe and the chimney made of earthenware pots or tinajas from which the bottoms have been removed.

In 1540 Coronado's expedition started in search of the seven cities of Cibola and later saw and conquered Acoma, and the Spanish padres or priests sought to convert the Pueblo people. The Pueblo Indians are a patient people and after years of patient toil they built an adobe church on the summit of the mesa. Every pound of clay was brought up the steep trail from the valley below on the backs of the Indians. The mesa was bare of soil. This was a herculean task when we consider the church is about 150 feet long and 50 to 60 feet high and the adobe walls are said to be from 7 to 10 feet thick. The timbers are 40 feet long and about 1 foot square, and there is no wood of this size nearer than Mt. Taylor, which is 20 miles distant. It was necessary to push these timbers up the trail after they had been carried for miles on the backs of the Indians.

The old church, which was slowly going to ruin and decay, was recently repaired by the Indians, the same year, in fact, that Prof. Libbey scaled the Enchanted Mesa, 1897. One is indeed fortunate to catch a glimpse of the inside of this church with its curious decorations and paintings. A writer in the *Catholic World*, for January, 1873, 16-703, says: "On one side of the altar was a painting of the Virgin and Child, on the other side was a painting of St. Joseph. On the ceiling above the altar were large paintings of the sun and moon, and here we got a chronological glimmer, the last we found. It was an inscription which stated that the church was renovated in 1802. The Indians said it was done by some artist priest who

came from far away, probably Spain or Italy. There are a pair of bells in the belfry. The Acoma tradition is these bells were a gift to the Pueblo from the Queen of Spain. They say they were given some time before the renovation of the church.

"The estufa at Acoma is an underground apartment descended through a trap door, which serves as a chimney. The smoke-begrimed ladder reaches to the bottom. The chamber is 30 feet in length and 15 feet wide and is used as a general place of meeting or public hall or club room. He found four Indians sitting around a fire, each wearing a blanket, the only other covering being a breech clout. It was the duty of these men to watch the fire, that was always kept burning, waiting for the coming of Montezuma. They were finally relieved by others. Francisco, a Pueblo Indian, unlocked a vast trunk of antique form and solidity and took out a pile of manuscript which he handed with solemnity. The first was a missal; the office of the Mass was copied in Latin, in a fair, plain hand, the work of a Spanish missionary. The ink was turned yellow, but the text was clear and legible; but there was no date. It also contained a register, in Spanish, of births and marriages. The earliest record of the Pueblo they found in the trunk was the record of a baptism in 1725. They then put the papers in the chest and locked it with a padlock nearly as large as a traveling satchel. He then sat down to a dinner of chicken stew made intensely hot by chile (red pepper).

"The women wore dark woolen robes made of two pieces about 5 feet long and 3 feet broad, sewed together at one of the narrow ends with an aperture for the head to pass through. The robe is then gathered round the waist and tied with a string. The arms are bare and encircled at the wrist by brass rings. The feet are bare and there is a thick swathing of buckskin to wrap the lower limbs."

The dead at Acoma are buried in a graveyard, but probably there is not another one like this on the continent. The mesa has a bare rocky floor, not an inch of natural soil produced by erosion; so these patient people built a stone wall about 200 feet square and filled it with soil brought with infinite toil from the desert plain below. The soil was brought in baskets or in earthenware vessels. It is stated that at the outer edge

there is a depth of 40 feet of soil. The priests have said that it took 40 years to complete it. Lummis says: "In the graveyard the dead of centuries sleep. The still form is swathed in the costliest blanket and lowered into their narrow bed and upon the earthen coverlet is broken the symbolic jar of water. From the belfry has pealed the last silver clang when they file to the houses where the shamans are blinding the eyes of the ghost that they may not find the trails of the vanished soul upon the four days' journey to Shipaipu. You may see brought forth jars, hand mills, weapons, ornaments and clothing to be broken and rent that they may go with the departed owner."

In an arid region the great desideratum is water, and the Acoma people are extremely fortunate in having a bountiful supply. There is a great natural tank or reservoir, which is really a depression or hollow in the sandstone rock. Here accumulates the water from the melting snows and the summer cloudbursts, for in the plateau region what rain does fall often comes down in torrents accompanied with a most vivid and startling display of lightning and a fearful cannonading. Although evaporation is rapid in this unusually dry atmosphere, still it is a source of perennial supply without which they could never have defied the Navajos and Apaches in their impregnable home. There is also a spring in the base of the mesa and the Acoma women make constant journey to both sources of supply, carrying the water in their earthenware vessels or tinajas securely poised on the head, which doubtless helps to insure an erect and graceful carriage.

On the occasion of our visit to Acoma quite a number of the men were at the summer pueblo, known as Acomita, which is from 12 to 15 miles distant. There is more water at this village and agriculture can be conducted more successfully, because they can irrigate in a small way and raise peaches, melons, beans and peppers. Agriculture cannot be successfully conducted and good crops raised where the rainfall is less than 20 inches a year without irrigation. At Acoma the rainfall is about 12 inches, yet they succeed in filling their storehouses with sufficient food to last them over winter.

At Acoma there is a very interesting *estufa* or underground chamber. You descend through a trap door and then down

a ladder and you find yourself in a room about 30 feet long and 15 feet wide. This underground room is a council chamber where matters of state are discussed. The Indians, wrapped in blankets, sit around a sacred fire which is never allowed to go out. It is always replenished with fuel. There they await the coming of Montezuma.

In 1598 Juan de Onate conquered Acoma. The Indians wanted him to scale the cliffs and descend into the estufa, but he wisely declined, which was fortunate, as the estufa was full of armed Indians.

The population of Acoma at the present time is between 500 and 600 peaceful Indians who never gave the Government any trouble. They have defended themselves against their enemies, the Navajos and Apaches, in the past. The Apaches, led by Geronimo, have been chased time and again over the border line into Mexico by the United States troops, but the Acoma Indians have been peaceful towards the United States and have never been moved to reservations.

G. W. James states in an article (*Scientific American Supplement*, Vol. 47-19488.) that Juan de Onate, who conquered Acoma, estimated the population in his epic as 3000, and says when Vincente attacked it the population was 6000 and that only 600 remained after the conflict. The author believes this estimate is entirely too high and greatly exaggerated. As before stated, that eminent authority, Bandelier, states the population of all the Pueblos of the entire Southwest never exceeded 30,000, and the population to-day of all the Pueblo villages is about 9000, so that it is not likely that the population of Acoma at any time in its history ever reached 6000 or that any expedition of the Spaniards ever slew so many. As a matter of fact, one of the most popular and wide-spread errors is the grossly exaggerated statement that the former Indian population of the United States was enormous, some writers' estimates reaching 16,000,000, and that the whites are responsible for their extermination. Major Powell, formerly head of the Bureau of Ethnology, scouts this idea, and Garrick Mallery, of the same Bureau, gives the results of a census taken in 1877, which puts the Indian population of the United States at about 300,000. In many of the tribes a decided increase in population was noticed, and in those tribes in which

a decrease was noticed the cause was sometimes due to absorption by marriage or the ravages of some contagious disease like small-pox. The Indian population of the United States has probably always been small as compared to the vast extent of country over which they roamed. Nevertheless there are reasons why many have the erroneous id  a that the former Indian population of the United States numbered millions. The early settlers who sailed up the broad estuaries of the Delaware and Chesapeake and took up their abode on the coastal plain of sands, marls and clay, saw many Indians, because they settled where there was an abundant food supply of ordinary fish and shell fish as well. When, however, the coastal plain was peopled they then settled the Piedmont Plateau, the rocky, rolling country to the westwards, between the coastal plain and the Appalachians; but when the mountains were reached the Indians were not so abundant, and long journeys might be taken and very few met with, the reason being the food supply was not so abundant there. The settlers took home to England exaggerated notions of the total Indian population. Then again, many of the tribes were migratory and changed camps often, which made them seem more abundant to the whites. The Appalachians were just as effectual a barrier to the Indians as to the whites, and our history proves that many of the settlers went south to Georgia where the Appalachians end and came round them to settle on the other side rather than cross them with their belongings. This is not to be wondered at, as the two principal ranges, the Blue Ridge and Allegheny Mountains, are 75 miles apart and were then covered with almost impenetrable forests on account of absence of roads. Then again the French voyageurs and trappers could never have made such long journeys up the Missouri and other rivers and return in safety to civilization if the Indians were as thick as flies. The West is a country of magnificent distances and the present white population has not crowded it as yet and will not for many years to come. There is no doubt that some tribes were almost exterminated by the whites, but as a rule they generally moved to another part of the country or were taken in by another tribe.

The Digger Indians occupied the region roughly between the Sacramento River and the State of Nevada. The Hunting-

ton Expedition, 1899-1903, estimates the present number at from 200 to 250; before association with the whites it is supposed they numbered about 4000. Why they have dwindled down to the present number is a question. They have no tradition of living elsewhere.

Coronado's expedition left Mexico in 1540 in search of gold and the seven cities of Cibola; they traveled through what is now Arizona and New Mexico and it is supposed they came as far east as Kansas. Probably from the Spanish manuscript of Castaneda's narrative most of the information we possess of this intensely interesting expedition is obtained. The following brief account of what part of the expedition thought of Acoma is taken from (the 14th Annual Report of the Bureau of Ethnology, Part I, page 490.) It is a translation of Castaneda's narrative, Chapter 12, of how the people came from Ciyuye to Cibola to see the Christians, and how Hernando de Alvarado went to see the cows: "While they were making these discoveries some Indians came to Cibola from a village which was 70 leagues east of this province, called Ciyuye. Among them was a captain who was called Bigotes (Whiskers) by our men because he wore a long mustache. He was a tall, well-built young fellow with a fine figure. He told the general that they had come in response to the notice which had been given to offer themselves as friends, and that if we wanted to go through their country, they would consider us as their friends. They brought a present of tanned hides and shields and head pieces which were very gladly received, and the general gave them some glass dishes and a number of pearls and little bells, which they prized highly, because these were things they had never seen. They described some cows (buffalos), which from a picture that one of them had painted on his skin, seemed to be cows, although from the hides this did not seem possible, because the hair was woolly and snarled, so that we could not tell what sort of skins they had. The general ordered Hernando de Alvarado to take twenty companions and go with them and gave him a commission for eighty days, after which he should return to give an account of what he had found. Captain Alvarado started on his journey and in five days reached a village which was on a rock called Acuco (Acoma), having a population of about 200 men.

These people were robbers feared by the whole country round about. The village was very strong, because it was up on a rock out of reach, having steep sides in every direction, and so high that it was a very good musket that could throw a ball as high. There was only one entrance, by a stairway built by hand, which began at the top of a slope which is around the foot of the rock. There was a broad stairway for about 200 steps, then a stretch of about 400 narrower steps, and at the top they had to go up about three times as high as a man by means of holes in the rock in which they put the points of their feet, holding on at the same time by their hands. There was a wall of large and small stones at the top which they could roll down without showing themselves, so that no army could possibly be strong enough to capture the village. On the top they had room to sow (?) and store a large amount of corn, and cisterns to collect snow and water. These people came down from the plain ready to fight, and would not listen to any arguments. They drew lines on the ground and determined to prevent our men from crossing these, but when they saw that they would have to fight, they offered to make peace before any harm had been done. They went through their forms of making peace, which is to touch the horses and take their sweat and rub themselves with it, and to make crosses with the fingers of the hands. But to make the most secure peace they put their hands across each other, and they keep this peace inviolably. They made a present of a large number of (turkey) cocks with very big wattles, much bread, tanned deerskins, pine (pinon) nuts, flour (corn meal) and corn."

It is interesting to recall that this quaint account of a visit to Acoma was written about eighty years before the Pilgrims landed on Plymouth Rock.

We who live in Pennsylvania, where the rainfall reaches forty-five inches per year, can scarcely realize how important even a slight rain is in the desert regions of the Southwest; a muddy reservoir means a great deal to the Indians. In the Extra Census Bulletin of the 11th Census it is stated: "A great deal of bad feeling existed between Laguna and Acoma on account of a storage reservoir which they had built together for mutual benefit. Many Laguna families own and hold fields in the Valley of Acoma up to a line separating their

territory from that of their neighbors, which had been agreed upon in years long gone by, and their rights recognized down to the present time; but last summer the people of Acoma denied them water from the reservoir, in consequence of which their corn crops were very poor. Laguna sent a delegation of their principal men to confer with a similar body at Acoma and demand their rights. Acoma claimed that there was not sufficient water for their own use, which statement Laguna denied, charging that Acoma was carelessly or intentionally wasting the water. They came to no settlement. The Governor of Laguna then appealed to the Indian Agent at Santa Fe, who paid no attention to his grievances. Finally, through another source, word was sent impressing upon the agent the urgency of the matter and the necessity of its immediate attention and settlement. He came down and went over to Acoma and was not well received. He went back to Santa Fe and the cornfields of the Lagunians in the Valley of Acoma went dry."

EFFECT OF MOISTURE ON THE STRENGTH AND STIFFNESS OF WOOD.

Very little is definitely known about the influence of moisture on the strength of wood, even by those experienced in handling the material. Since the whole subject is one of great importance, the Forest Service has been making a thorough study of it during the past three years and is about to publish the results of its investigation in an exhaustive technical bulletin entitled, "Effect of Moisture upon the Strength and Stiffness of Wood."

The chief points presented by the study are:

1. The relation of moisture to strength follows a definite law which can be graphically expressed. Proper drying very greatly increases the strength of all kinds of wood, the amount of increase in strength depending upon the species and the dryness. The increased strength given to green wood by thoroughly drying it is so great that it will surprise many. For example, the strength of a piece of unseasoned red spruce may be increased over 400 per cent. by a thorough drying at the temperature of boiling water. Strength decreases again, however, as the wood reabsorbs moisture. Air-dried wood, protected from the weather, and containing 12 per cent. of moisture, is from 1.7 to 2.4 times stronger than when green, varying with the species. Stiffness is also increased by drying. These conclusions, however, are drawn from small-sized pieces, not exceeding four by four inches in cross-section, such as are used in vehicle work, tools, etc. Large timbers require years of drying before the moisture is re-

duced to the point where strength begins to increase. It must also be taken into consideration that more or less checking always occurs when large timbers dry; and if this checking is excessive it may cause weakness to counterbalance, partially or entirely, the strength gained in drying. Consequently it is not safe to assume that the average strength of large, so-called seasoned timbers is much greater than that of green or wet ones.

2. The fiber saturation point of a number of species has been determined. This point, which varies with conditions and species of wood, designates the percentage of water which will saturate the fibers of the wood. It has been found that, under normal conditions, wood fiber will absorb a definite amount of moisture; beyond this the water simply fills the pores of the wood like honey in honey-comb. Only that water which permeates the wood fiber has an influence upon the strength. For the following species, the saturation point occurs at the given percentage of moisture based on the dry weight of the wood:

Longleaf pine.....	25	per cent. Moisture.
Red spruce.....	31	" "
Chestnut.....	25	" "
Loblolly pine sapwood.....	24	" "
Red gum.....	25	" "
Red fir.....	23	" "
White ash.....	20.5	" "
Norway pine.....	30	" "
Western tamarack.....	30	" "

3. Prolonged soaking in cold water does not reduce the strength of green wood below that of its fiber saturation point, provided it remains in perfect condition. When wood has been dried and is resoaked, it becomes slightly weaker than when green.

4. Wood soaked in heated water absorbs more moisture because the amount of water which the fiber will contain is increased. This causes a reduction in strength and stiffness, as in wood that is heated or steamed for bending.—(United States Dept. of Agriculture, Forest Service.)

THE RECOVERY OF ARSENIC.

Attempts are now being made to recover the arsenic which goes to waste in the smelter fumes at Anaconda, Mont. This is gratifying, since Mr. C. C. Schnatterbeck points out in a forthcoming report of the United States Geological Survey on the production of arsenic in 1905 that the United States should manufacture all the arsenic and arsenical compounds it may need instead of being obliged to make importations. Arsenic is recovered also from arseno-pyrite mined in Washington and from the ores which occur in Virginia. It is a curious fact that every year several hundred tons of arsenic sulphide obtained in purifying sulphuric acid at chemical manufacturing works are wasted. This object offers an opportunity for profitable research to those whose inventive minds may evolve an economical method of treating this arsenious by-product so that it may become of industrial value.

Mechanical and Engineering Section.

(Stated meeting held Thursday, November 1, 1906.)

Direct Leakage of Steam Through Slide Valves.

BY J. V. STANFORD,

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When the weight of steam used in an engine, as determined by condensing the exhaust, is compared with that computed from the indicator card, it is well known that there is considerable difference in the results. This difference between the actual and computed weights, commonly called "the missing quantity," and in some cases amounting to as much as 50 per cent. of the steam used, is generally considered as being accounted for by condensation in the cylinder. The indicator card shows only the actual weight of vapor in the cylinder at a given time, taking no account of the steam which has entered the cylinder and has been condensed by transfer of heat to the cylinder walls. There is no doubt that a large part of the missing quantity may be charged up to cylinder condensation, but there is a possibility that some of it may be due to another cause, namely, valve leakage.

Leakage through the valves of a steam engine may affect the results of an investigation of the engine in various ways. If the steam valves of a Corliss engine leak steam to the cylinder after cut-off, the indicator card should show the expansion line carried above its normal position, and a determination of the steam used, based on the pressure and volume near the end of the stroke, would probably include this leakage. If the exhaust valves leak, however, the expansion line will fall off, and a calculation from the card as before would fail to show the leakage, which would then become part of the missing

quantity. In the case of a slide valve, practically the same thing is true; any leakage from the steam chest to the cylinder will be taken care of by the indicator card, but leakage to the exhaust, either from the cylinder or chest over the bridge, or from the steam chest past the sides of the valve, is not shown by the indicator card, but forms part of the weight shown by the condenser.

The object of this paper is to give the results of some experiments that have been made at the Mechanical Laboratory of the University of Pennsylvania, to determine some facts in connection with leakage of slide valves.

A set of tests was made on a 6"x9" Sturtevant blower engine, driving a three-quarter housed centrifugal fan keyed direct to the shaft. The engine and fan had been installed in the boiler house of the University to create forced draft, and after a short period of use had stood idle with only an occasional run when used by the students for practice in valve setting. The engine has no governor, depending upon the throttle and the steady resistance of the fan to maintain the proper speed, and the valve is driven direct by the eccentric through a rocker arm.

The valve is of the common D slide valve type, 5 inches wide by $4\frac{3}{4}$ inches long, overlapping the ends of the ports $\frac{1}{4}$ -inch on either side. The engine had evidently been designed to work with the cut-off fixed at about .65 of the stroke, and during the tests the valve was set to give this cut-off. With this setting the minimum width of bridge covered by the valve was $\frac{5}{8}$ -inch, so that the exhaust port was everywhere protected from direct leakage by contact between the valve and seat at least $\frac{1}{4}$ -inch in width.

A balance plate extends between the valve and chest cover to relieve the pressure between the valve and seat, and reduce the resulting friction. The balancing device consists of a cylindrical cup, bearing against a circular boss on the chest cover, and telescoping over a cylindrical projection from the top of the valve, the telescoping joint being made tight by two split rings. Contact is maintained between the balance plate and chest cover by four light springs. Steam leaking through the packing rings to the inside cavity of the balance plate is discharged through two $\frac{3}{16}$ -inch holes in the top of the valve

direct to the exhaust cavity, so that the pressure over a large part of the valve is exhaust pressure. This leakage is also part of the missing quantity, for it goes to the condenser without affecting the indicator card.

In preparing for the tests, the engine exhaust was piped to a surface condenser, and arrangements made for collecting and weighing the condensation: a pressure gauge was attached to the steam chest and a revolution counter geared to the eccentric strap. Indicator cards were also taken.

Two runs were then made with the engine working normally under the load of the fan, with the balance plate on the valve, and readings were taken to give weight of steam condensed, revolutions per minute, pressure in the steam chest, and the indicated horse power. Average results from the two tests showed that the engine was developing about 5.13 horse-power, and was using about 91.2 pounds of steam per indicated horse-power per hour.

The balance plate was then removed from the valve, the holes through the top of the valve plugged with wood, leaving the valve unbalanced, and tests run as before. These tests gave a steam consumption of 60.5 pounds per indicated horse-power per hour, or 30.7 pounds less than when the balance plate was in place, due to the difference in leakage.

In the first case the leakage was through the balance plate and under the valve; in the second case under the valve only, but the difference was probably due, not so much to leakage through the balance plate, as to the fact that in the first case the valve was only lightly seated, while with the balance plate removed it was seated firmly by the whole pressure of the steam and a good joint maintained with the seat.

In order to determine the actual amount of leakage, the steam ports of the engine were plugged by driving in blocks of dry white pine, filling the steam passages flush with the valve seat. One cylinder head was then removed and the stuffing box opened to relieve any pressure in the cylinder due to leakage through the plugs. The eccentric sheave was loosened on the shaft and bolted to a large wood pulley placed beside it. The pulley was belted to a one horse-power electric motor, geared to drive the pulley and eccentric about the shaft at the same speed as had been used in the previous tests. Having

thus reproduced the conditions of running of the valve as nearly as possible, except that all passage of steam to and from the cylinder was eliminated, it was fair to assume that all the steam now reaching the condenser was due to leakage from the chest to the exhaust and that the amount was practically the same as when the engine was running normally. In running these tests, the motor was started and adjusted to the proper speed, then the throttle valve was opened carefully until the pressure in the chest was the same as in the other tests. Considerable difficulty was experienced in making the wooden plugs in the steam passages hold the pressure, and several were blown through into the cylinder before the experiment succeeded, with no disastrous effect, of course, for the cylinder ends were open, and the piston stationary.

A test under these conditions, with the balance plate on, showed leakage amounting to 43.9% of the total steam consumption of the engine as determined by the first tests; when the balance plate was removed, the leakage was 13.9% of the steam consumption.

In order to verify the assumption previously made that the excessive leakage with the balance plate on was due to imperfect seating of the valve when balanced, tests were run with the balance plate off and with varying pressure in the chest, when it was found that the leakage decreased rapidly as the pressure increased.

As stated before the engine had been standing idle for some time and the valve and seat were not in perfect order, but their condition was not unusually bad, for when tested in the ordinary manner by opening the throttle with the valve standing still over the ports only a trifling leakage was apparent, which makes it appear that the standing test for leakage, so commonly used, is a very poor index of what may take place when the valve is running.

In order to determine the effect of the balance plate in reducing the work required to drive the valve gear, the electric motor driving the eccentric was calibrated for efficiency and wattmeter readings taken, giving data for computing the power absorbed by the eccentric and valve under varying conditions. It was found that the power used with the balance plate on was .25 horse-power, and that it remained practically

constant for varying pressures in the chest. Without the balance plate, the power required increased with the pressure and amounted to .38 horse-power for the pressure previously used. While the saving shown here is slight, the value of the balance plate for much larger valves is unquestioned, and no doubt results in a net saving when the parts are in perfect working condition, but it would seem that in a small engine receiving the ordinary care, its presence may become detrimental in the course of time, owing to its tendency to increase the leakage due to poor contact between the valve and seat.

METALLICS.

A heavy expense in conducting the asphalt business is the price of barrels for containing the product. No cheap substitute has yet been found.

Most of the oil asphaltum made in California is a by-product from the distillation of lubricating and illuminating oils and lighter products from crude petroleum, which has an asphaltic base.

Internal strains in iron and steel are the result of stresses within the mass of the piece, some parts being in tension and some in compression, each part striving to relieve itself from strain and make the piece assume a form in which all parts are at rest.

R. S. Woodward has computed that, assuming the average density of the earth's crust to be 2.75, the density at the center is 10.74, and at 100 miles depth it is 3.03. Owing to the rigidity of the rocks, no increase in density is manifest above a depth of five miles.

Calumet and Hecla copper is particularly free from natural impurities, showing 99.89 per cent. of copper; 0.1 per cent. of oxygen, and 0.01 per cent. of iron and arsenic. Its electric conductivity, when drawn to 0.104-in. diameter, as 99.5 to 100 Mathiesson standard.

Aluminum bronzes containing less than 4 per cent. aluminum are easily worked, but beyond that point the bronze becomes hard to work. Such a bronze can be rolled, but wire cannot be drawn from it. With 6 per cent. and over of aluminum the metal cannot ever be rolled.

Pure gypsum contains 79.1 per cent. of calcium sulphate and 20.9 per cent. of water. Deposits of gypsum large enough to be worked for plaster are, however, rarely even approximately as pure as this. Gypsum used for plaster usually carries varying, and often high, percentages of clay, limestone, dolomite, iron oxide, etc.

When alloyed with copper, aluminum acts similarly to zinc, but much more strongly, so that an addition of 1 per cent. aluminum produces as much effect as 3.5 per cent. of zinc. Aluminum bronzes are much stronger than ordinary brasses, but those containing 10 per cent. or more of aluminum are so hard that they cannot be worked.

Portland cement made in the United States is formed from four combinations of materials: Argillaceous limestone and pure limestone; marl and clay; chalk and clay; hard limestone and clay or shale. More than half of the total portland cement of the United States is now made from the first-mentioned pair, but that from the last-mentioned group is rapidly increasing.—*Eng. and Mining Journal*.

COMPARATIVE STRENGTH OF GREEN TAMARACK AND GREEN NORWAY PINE.

A series of tests to determine the relative strength of green tamarack and green Norway pine timber has recently been made by the Forest Service of the United States Department of Agriculture at the timber testing laboratory at Purdue University, Lafayette, Indiana. The material was furnished by the Kettle River Quarries Company of Minneapolis, and nearly all of it grew in St. Louis County, Minnesota. The strength values obtained apply only approximately to timber of the same species grown elsewhere.

Bending tests were made upon beams with a span of thirteen feet six inches and ranging from four by ten to six by twelve inches in cross-sections. From these tests, showing the strength and stiffness of sound green tamarack and Norway pine in structural sizes, the results were as follows:

Strength	
(Modulus of rupture).....	Tamarack.....4,600 lbs. per sq. in.
	Norway pine.....4,000 " " " "
Stiffness	
(Modulus of Elasticity)....	Tamarack.....1,240,000 " " " "
	Norway Pine.....1,189,000 " " " "

Green tamarack thus appears to be uniformly stronger and stiffer than green Norway pine. When oven-dry tamarack weighs twenty-nine pounds per cubic foot and Norway pine about twenty-four pounds per cubic foot.

Tamarack is usually of slower growth than the pine. Bending tests on small clear pieces indicate that strength decreases in tamarack when the rate of growth is faster than an inch in eight years, and in Norway pine when the growth is faster than an inch in ten years. Comparative tests on the seasoned timber of the two species will be made later.

AN ALLOY of sixty parts copper, one part tin and thirty-nine parts zinc, is found to offer great resistance to the action of sea water, and has been largely used in naval construction.

Section of Photography and Microscopy.

(*Stated meeting held Thursday, October 25th, 1906.*)

Supplementary Illumination.

BY MR. JOHN BARTLETT.

At a recent meeting of one of our learned societies an interesting discussion took place as to the keeping qualities of orthochromatic plates.

The concensus of opinion was that they not only deteriorated by age, but that even proper exposures which remained undeveloped for some time had a tendency to fog when developed, comporting themselves similar to originally over-timed plates.

The important suggestion was made that the substances employed in orthochromatising had the power of absorbing light and so probably continued the action to such an extent as to act injuriously upon the plate.

Of course the truth of such a supposition requires careful investigation, but when we call to mind that the majority of the chemicals used to give color-values, exhibit phosphorescent or fluorescent qualities, there may be some reason for the supposition.

The inertia of the plate must be overcome by the impact of light before it is possible to get a latent image, and so the absorbed light may act as a sort of spur, or in other words, give to the plate an impetus.

We know that even with our extremely rapid plates there is a limit to the speed at which the shutter does act, even under the brightest illumination.

In the days of wet collodion practice the photographer sought to stimulate the speed of the plate by subjecting it for

a brief interval to the influence of light before or after exposure in the camera. It was claimed that this "flashing," as it was called, tended to bring out more detail, the parts of the plate already under the influence of the light, accepting this impetus which the unexposed portions were not able to avail themselves of.

Some went so far as to insert actinic colored glass in the diaphragm of the lens. Others colored the interior of the camera white or blue in the belief the action of light was increased thereby.

Some years ago a method of auxiliary lighting was recommended to increase the sensitiveness of albumen printing-out paper. It was found that if a piece of silvered paper was exposed for a short time to light no apparent visible effect was noticeable, but when an image from a negative was printed on it, the impression, or print, came up much more rapidly at first than it did upon a piece of paper not previously subjected to the "flashing" process. This might go to show that auxiliary lighting sets up an accelerating or continuing action.

This flashing method, we may here remark, was found to be of little practical value to the hurried photographic printer, the spur or impetus lasting only for a brief time, the print on the unexposed paper catching up and progressing along with the other, both finishing at about the same duration of time.

In the course of some recent experiments toward producing a uranium paper, very sensitive to the action of artificial light, I placed a sheet of coated paper (the salt being an axalate of uranium) in a portfolio in contact with an engraving. In less than a day thereafter on opening the book I was surprised to find a beautifully distinct impression of the print. I say "surprised," not because the impression was there, but because the paper had been coated in a very feeble light and therefore could have absorbed but very faint radiations.

The subject of uranium radiations would lead us too far afield, and besides I would hardly venture any opinion just now about a topic with which I am but little acquainted.

But the question of fog in photography does suggest itself. I have often asked myself what is fog? without any oracular response. What is this disturbing element in development which brings down the anathemas of the photographer? May

it not after all be a potency for good, if only controllable like the other potencies of nature? Perhaps a valuable accessory in development.

Shakespeare tells us

"There is a spirit of good in things evil—"

and why not seek for this good eliminating the evil?

Perhaps we are in a foggy mood ourselves just now, but we cannot refrain from complaining, Why has so little been accomplished in what might be called the philosophy of photography? Despite the labors of eminent men of science and the exhaustive manner in which most scientific problems are treated, comparatively little inquiry is made into the rationale of photographic phenomena.

In this age of vigorous scientific research the neglect is hard to be accounted for. Scientific photography is neglected too much in the storm and stress of art culture. Our exhibitions of late years are wholly given up to a particular phase of aesthetic feeling called photographic impressionism. Doubtless excellent in its way and important in its direction, but we cannot help thinking that it would repay the patient investigators after scientific truth to devote some of their energy in the direction of photography. With few exceptions, of late the researches in photography have been rather desultory. It may be necessary to toil all night before the morning yields success; but nothing is denied to well-directed effort.

What do we know about the latent image? What has been done to clear up the conception about solorisation? Doubtless discoveries lie hid which might be brought to light by a careful and systematic course of observation and experiment. It may be that some clue to the mystery of the latent image is involved in the understanding of the phenomena of fog or solorisation. Experience shows us continually how one phenomena depends upon another, but the inductive method seems to have less favor with photographic investigators than the deductive. A theory is set up and facts made to conform thereto, instead of the general principle being an evolution from the facts. We appreciate the great factor of the imagination in scientific discovery, but the temptation must be constantly avoided of wandering off by devious paths from the

straight and narrow way which leads to truth. The only method, we repeat, is to build up from facts observed; to deliberately assemble all parallel instances we can muster; to experiment, rather than passively observe.

Book Notices.

Emery Grinding Machinery: A text-book of workshop practice in general tool grinding, and the design, construction and application of the machines employed. By R. B. Hodgson, A. M. Inst. Mech. E. (2vo., 180 pages.) London: Charles Griffin & Co., Ltd. Philadelphia: J. B. Lippincott Co.

The author has intended in this volume to prepare a handbook of workshop practice in the methods and machinery employed for grinding, sharpening and polishing metals by means of the emery wheel. The work is profusely illustrated. W.

Carborundum: Von Francis A. J. Fitz-Gerald. Ins Deutsche übertragen von Pr. Max Huth. Mit 9 Figuren und 3 Tabullen im Text. (8vo., 44 pages). Halle a. S. Verlag von Wilhelm Knapp. 1904. (Price, M, 2.)

This volume constitutes the xiii volume of the admirable series of monographs on Applied Electrochemistry that have been issued for a series of years from this publishing house. The author was for years the superintendent of the Carborundum Co., and his exposition of the subject will be accepted as authoritative. W.

Change Gear Devices: By Oscar E. Perrigo. 8vo., pp. 81. New York. The Locomotive Publishing Co., Ltd. (n. d.)

This work is principally a reprint of a series of articles which appeared originally in the columns of "Machinery," and contains the results of an exhaustive examination of the development of the art of constructing change gears for engine lathes, as represented by the patent literature on the subject. Those who are interested in the subject will doubtless find in it much information of value. W.

Physics: By Charles Riborg Mann, University of Chicago, and George Ransom Twiss, Central High School, Cleveland. (8vo., 453 pages). Chicago: Scott, Foresman & Co. 1905. (Price, \$1.25.)

This volume is the joint work of two instructors, one a well-known University professor, and the other a High School teacher, and is arranged for the use of pupils along the lines indicated by their extended experience in teaching. W.

Jahrbuch der Elektrochemie und angewandten physikalischen Chemie. Berichte über die Fortschritte des Jahres 1904. Herausgegeben von Dr. phil. Heinrich Dannell, Breslau, XI Jahrgang. Halle a. S. Verlag von Wilhelm Knapp. 1906. (Price, M. 25.)

This imposing volume of nearly 1000 pages, large octavo, gives an intelligent summary of all the important contributions to the science of electrochemistry that occurred in the year 1904. Like its predecessors of the same series, it is admirably printed and illustrated.

The volume is compiled with the coöperation of a number of noted experts, and no branch of this important and growing department of electrical science is overlooked. W.

PUBLICATIONS RECEIVED.

U. S. Department of Agriculture, Weather Bureau, Bulletin No. 37. Recent practice in the erection of lightning conductors, prepared under the direction of Willis L. Moore, Chief U. S. Weather Bureau, by Alfred J. Henry, Professor of Meteorology. 20 pages, 8vo. Washington, Gov't Printing Office, 1906.

Sixth Annual Report of the Chief of the Mining Bureau to the Honorable Secretary of the Interior, by H. D. McCaskey, Chief of the Mining Bureau, being for the year ending August 31, 1905. 66 pages, plates, maps, 8vo. Manila, Bureau of Printing.

Michigan State Board of Health. Teachers' Sanitary Bulletin for October, November and December, 1905. Three pamphlets, 8vo. Lansing.

Niles Electric Traveling Cranes, for use in stone yards, freight yards, lumber yards, storage yards. Niles-Bement-Pond Company. 19 pages, illustrations, oblong, 16 mo. New York, 1906.

Publications of the Women's Auxiliary of the Massachusetts Civil Service Reform Association. A primer of the civil service and the merit system, by Elizabeth Luther Cary. 14 pages, 24 mo.

The civil service, merit system, the spoils system, by Edward Cary, Document No. 3. 13 pages, 12 mo. Boston, 1905.

The merit system in municipalities, by Clinton Rogers Woodruff. Document No. 6. 14 pages, 12 mo. Boston, 1905.

Brown and Sharpe Manufacturing Company, catalogue of machinery and tools, 1906. 514 pages, illustrations, 24 mo. Providence, R. I.

U. S. Department of Agriculture, Bureau of Chemistry, Bulletins Nos. 64, 74, 78, 95 and 96. The influence of environment upon the composition of the sugar beet, by Harvey W. Wiley, Chief of the Bureau, with details of the annual experiments and a general summary of the five-year investigation, 1900-1904. 229 pages, illustrations, 8vo. Washington, Gov't Printing Office, 1905.

Le Salon de l'Automobile 2-24 December, 1905. Edition de la Revue Technique. 332 pages, illustrations, folio. Paris, Revue Technique, 1905.

Twenty-second Annual Report of the United States Civil Service Commission for the year ending June 30, 1905. 282 pages, 8vo. Washington, Gov't Printing Office, 1905.

Publications of the Bureau of Government Laboratories, Department of the Interior, Philippine Islands. No. 34. Birds from Mindoro and small adjacent islands. Notes on three rare Luzon birds, by Richard C. McGregor. 31 pages, plates, 8vo.

No. 35, five articles on the plants of the Philippines. 99 pages, 8vo. Manila, Bureau of Printing, 1905.

Practical Perspective. A practical explanation of the only practical perspective (isometric), by Frank Richards, associate editor "American Machinist," and Fred. H. Colvin. 59 pages, illustrations, 8vo. New York, Derry-Collard Co., 1905. Flexible cloth. 50 cents.

Der Bau einer Modernen Lokomotive (nach Angaben der Baldwin Lokomotiv-Werke mit 30 in den text gedruckten Netzätzungen) von Ingenieur Dr. Robert Grinshaw. 34 pages, illustrations, 8vo. Hannover, Author, 1905. Paper, 50 pfennig.

Sections.

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—Thirty-ninth stated meeting, held Thursday, October 25th, at 8 o'clock. Dr. Henry Leffmann in the chair. Present, eighteen members and visitors.

The first communication on "The Micro-organisms connected with the transmission of Hydrophobia," was read by Dr. Leffmann.

In the course of his remarks, Dr. Leffmann referred at some length to the literature and the history of the disease commonly known as hydrophobia, and then called attention to a recently published monograph on hydrophobia, by Anna Wessels Williams and May Murray Lowden, giving an account of some highly interesting experimental work done by the authors in the Research Laboratory of the Department of Health, New York City. They confirm the conclusions of Negri, that a specific microbe is the cause of the disease. They find the so-called "Negri" bodies invariably present in cases of the disease, and absent in animals not so afflicted.

The subject was discussed by Dr. Wahl and Dr. Edward Goldsmith.

The second communication entitled "Supplementary Illumination," by Mr. John Bartlett, was, in the author's absence, read by the Secretary. It related chiefly to the causation of what is known as "fog" in the development of photographic plates.

The paper was freely discussed by Dr. Goldsmith, Prof. Edward A. Partridge, Mr. Waldemar Lee, the President and the Secretary. The paper was referred to the Committee on Publications.

Adjourned.

M. I. WILBERT, *Secretary.*

MECHANICAL AND ENGINEERING SECTION.—Stated meeting, held Thursday, November 1st, 1906, 8 P.M.

Mr. James Christie in the chair.

The paper of the evening was read by Mr. J. V. Stanford, Asst. Prof. in the Mechanical Engineering Department of the University of Pennsylvania, on "The Direct Leakage of Steam through Slide Valves."

The paper dealt with the leakage of steam through the slide-valve of a small engine, and gave the results of tests made to determine the power used to operate the valve and the leakage both with the valve balanced and unbalanced.

The paper was discussed by Mr. Hugo Bilgram, Mr. Henry F. Calvin, Mr. James Christie and Mr. John C. Parker.

The meeting passed a vote of thanks to the speaker for his interesting communication and was adjourned.

FRANCIS HEAD, *Secretary*.

SECTION OF PHYSICS AND CHEMISTRY.—Stated meeting, held Thursday, November 15th, 1906. Dr. Wahl in the chair.

Present, twenty members and visitors.

The Chairman introduced Mr. R. E. Doolittle, Chief of the Government Food Inspection Laboratory, at New York, who presented a paper on "The Inspection of Imported Food." The speaker gave a detailed account of the methods employed under the operation of the recently enacted pure food laws, to insure the purity of articles of food and drink imported into the United States.

The paper was discussed by Mr. Waldemar Lee, Dr. W. J. Williams and Mr. Doolittle.

A vote of thanks was passed to the speaker of the evening for his interesting and instructive paper. Adjourned.

EDW. A. PARTRIDGE, *Secretary*.

Committee on Science and the Arts.

(Abstract of proceedings of the stated meeting held Wednesday, Nov. 7th, 1906.)

MR. HUGO BILGRAM in the chair.

The undermentioned report was adopted:

(No. 2379.) *Detector for Electrical Oscillations*. Louis H. Walter and Prof. James A. Ewing.

This report is reserved for publication in full.

Briefly, the device is one for detecting and measuring oscillating electric currents of high frequency and small volume; a quality which enables it to be used as a receiver in wireless telegraphy, for which service, the Committee report that it possesses all the qualities desired for successful operation. The award of the John Scott Legacy Premium and Medal is recommended to the inventors. (Sub-Committee: Thos. Spencer, Chairman.)

The following report passed first reading:

(No. 2394.) *The Monarch Engine Stop and Speed Limit System.* Consolidated Engine Stop Co., New York. (Laid over for one month under the rules.)

The following protest was made:

(No. 2382.) *Etch-Powdering Machine.* Louis E. Levy, Philadelphia. Applicant presented and filed with the Committee a letter of protest against the awards of the Committee in this case.

A motion to reconsider the Committee's action was offered by Mr. H. F. Calvin, and seconded by Dr. Edward Goldsmith. Action thereon will be taken at the stated meeting of December 5th inst.

WM. H. WAHL, *Secretary.*

The Franklin Institute.

(*Proceedings of the stated meeting held Wednesday, November 21st, 1906.*)

DR. EDWARD GOLDSMITH in the Chair.

Present, fourteen members.

Additions to membership since last report, seven.

Mr. Edwin Swift Balch read a paper on "The Survival of the Shortest and the Easiest in Language."

The speaker made a plea for the simplification of the spelling of many English words—especially such as are extensively employed in trade and commerce—with the object of securing a wider use of English in the commercial world. He especially urged the adoption of the reformed spelling by the commercial and trade journals.

The paper was discussed by Mr. Henry F. Calvin, Dr. Edw. Goldsmith, Dr. Wm. H. Wahl, the author and others.

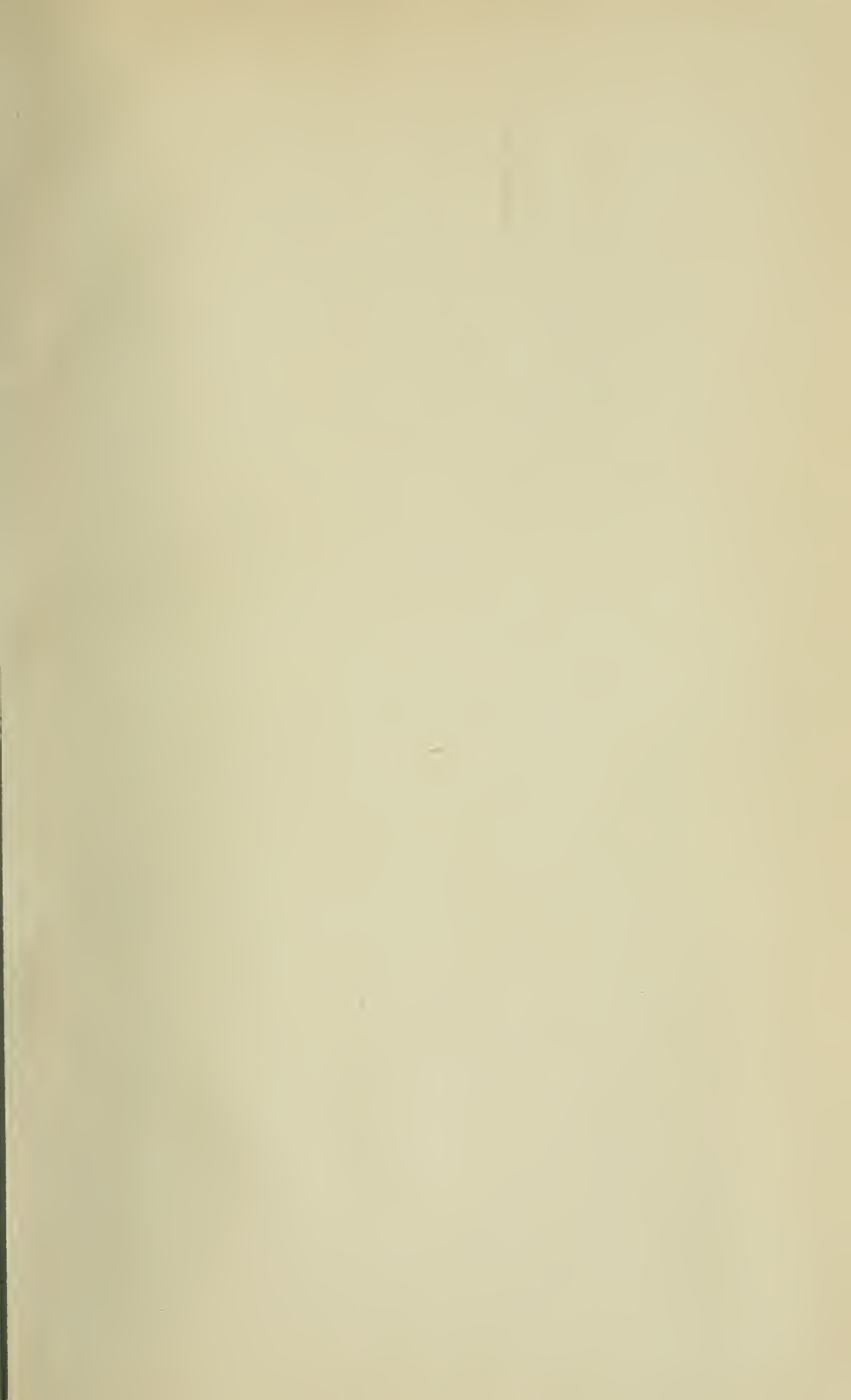
Mr. Harvey M. Watts, of Philadelphia, presented a communication entitled "The Why of the Weather."

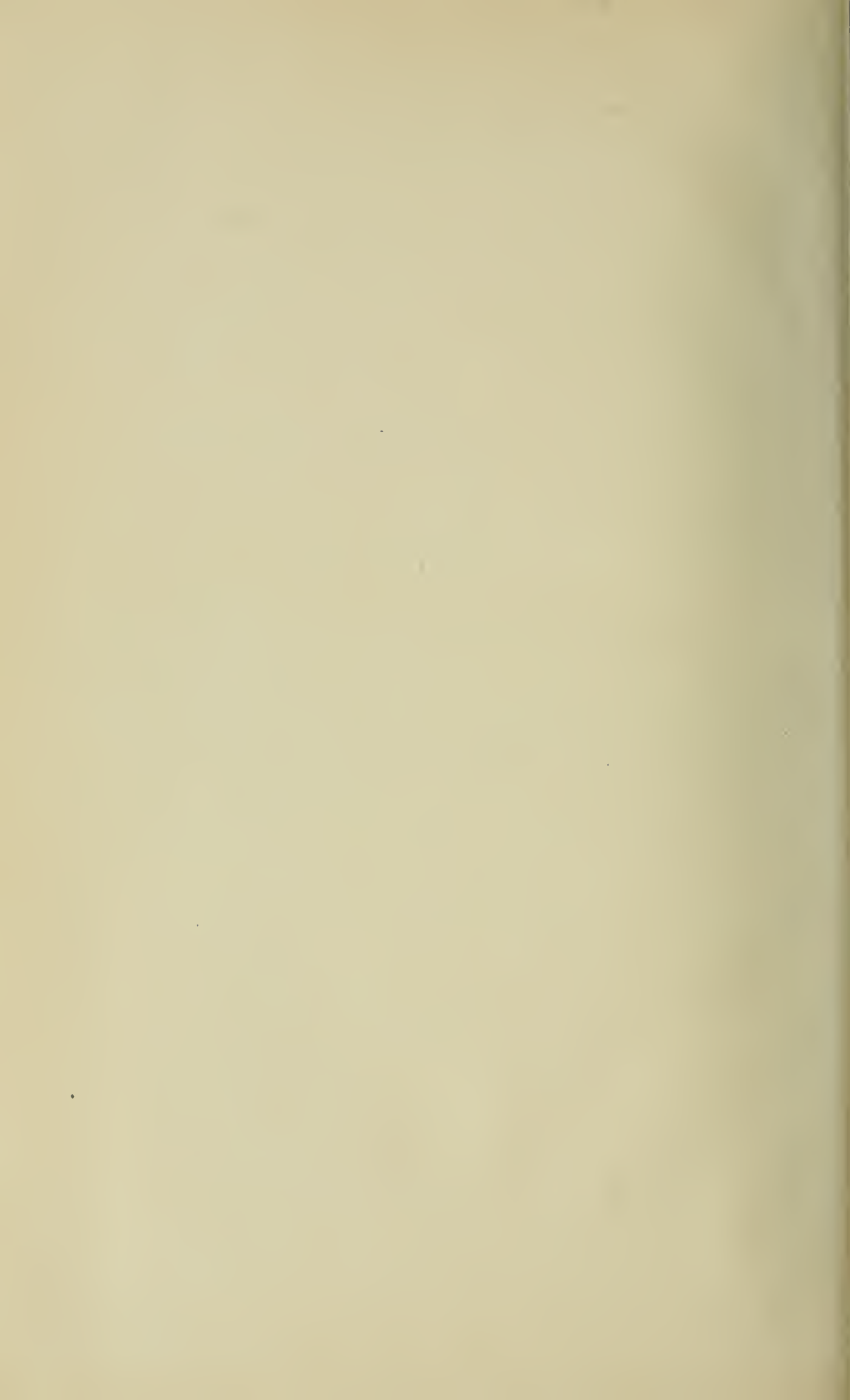
Mr. Watts discussed the general causes of weather and climate in the light of the most recent advances in meteorology, showing the interdependence of weather conditions the world over, and what are the definite factors in the extraordinary variations which occur in the weather and climate from year to year and over long-range periods. The speaker's remarks were freely illustrated with the aid of lantern slides.

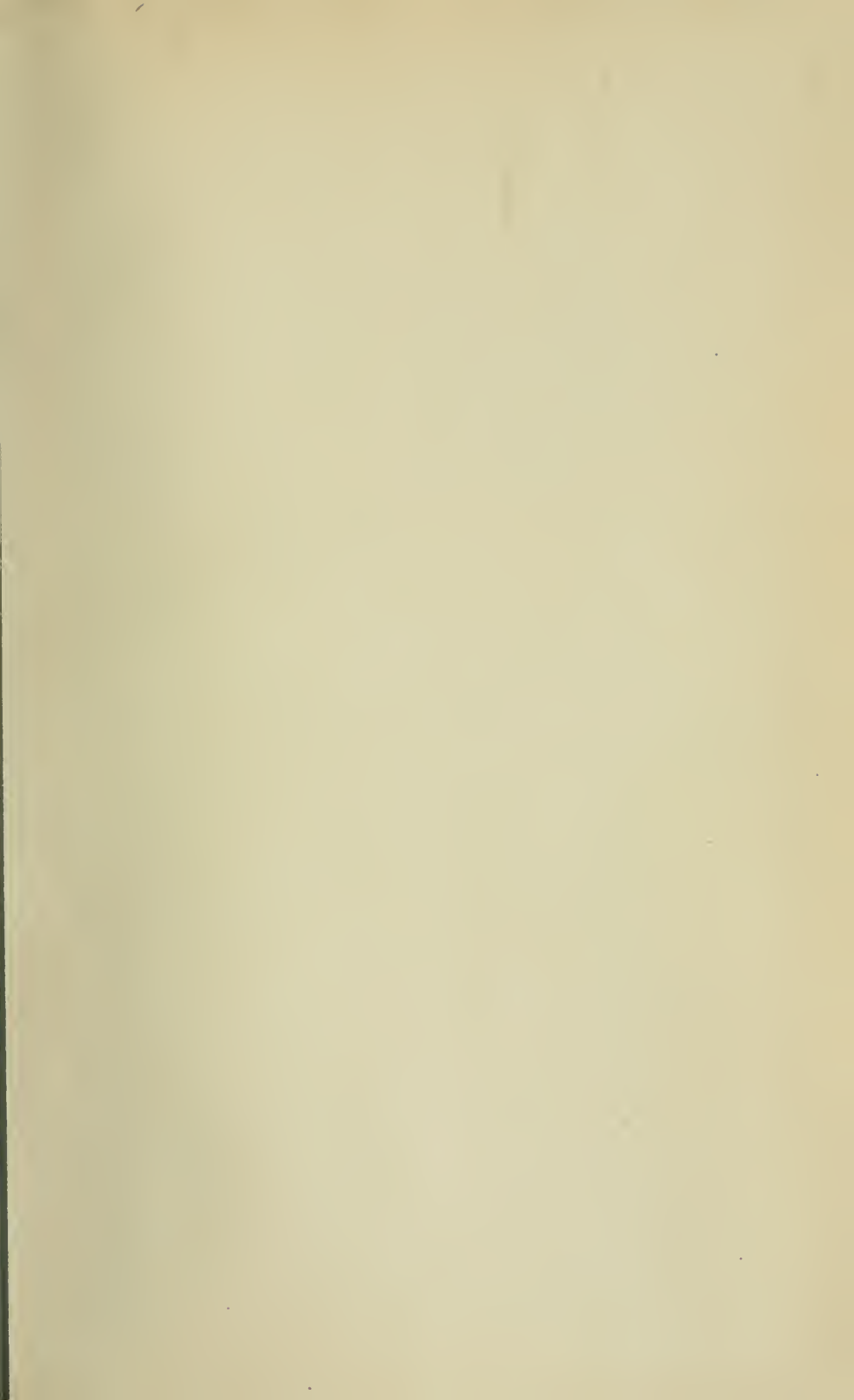
The communication was discussed by Messrs. Balch, Calvin, Goldsmith, Wahl and the author.

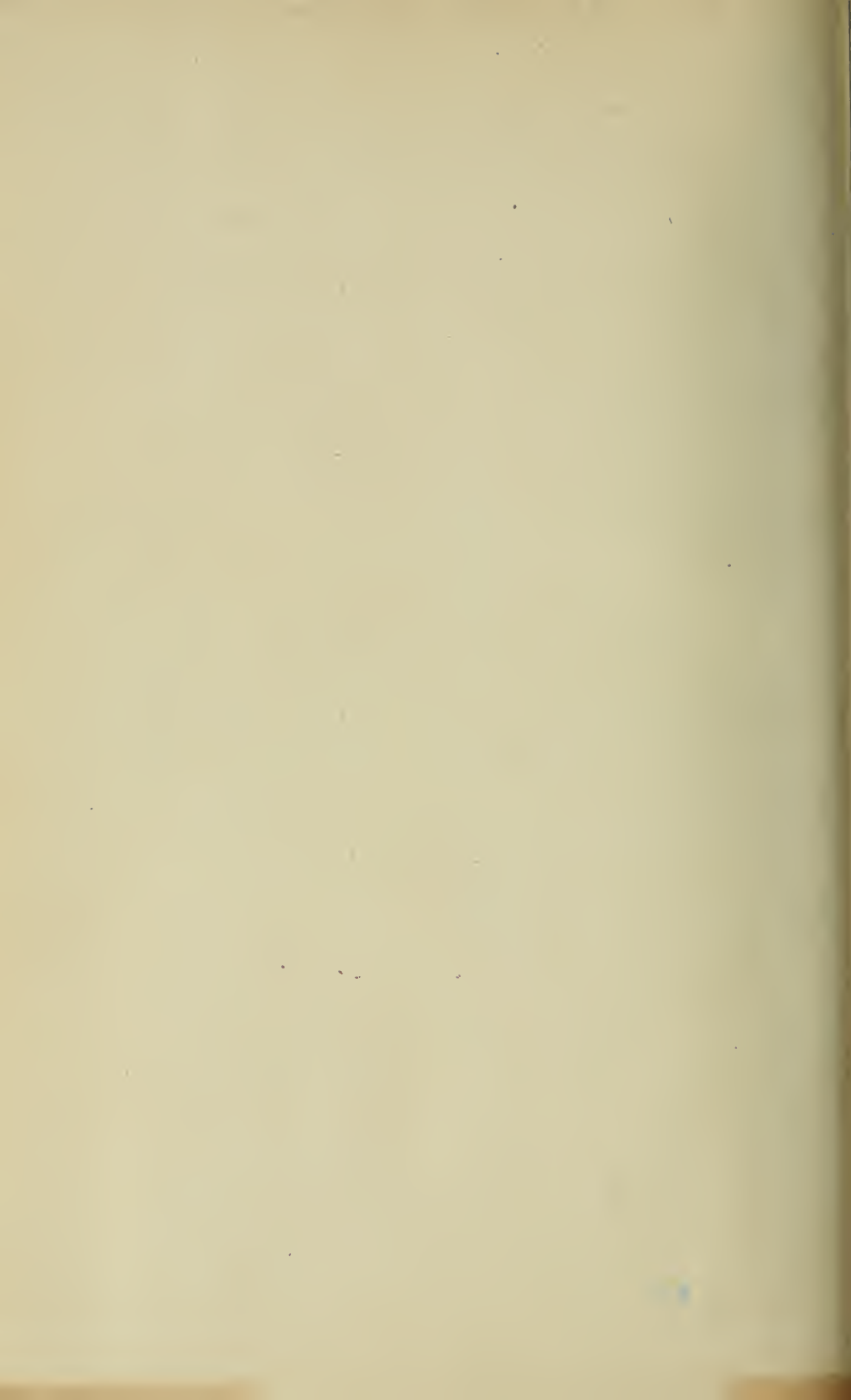
By vote, the thanks of the meeting were extended to the two speakers of the evening. Adjourned.

WM. H. WAHL, *Secretary.*









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